HANDBOOK
FOR
PROTECTION ENGINEERS

Authored by

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HANDBOOK FOR PROTECTION ENGINEERS

PROTECTION CIRCUITARY

ALL RELAYS, CIRCUIT BREAKERS

(INDICATION, CLOSE TRIP, ALARM & INTERLOCK CIRCUITS)

ACKNOWLEDGEMENTS

The ‘Hand Book’ covers the Code of Practice in Protection Circuitry including standard lead and device numbers, mode of connections at terminal strips, colour codes in multicore cables, Dos and Donts in execution. Also principles of various protective relays and schemes including special protection schemes like differential, restricted, directional and distance relays are explained with sketches. The norms of protection of generators, transformers, lines & Capacitor Banks are also given.

The procedures of testing switchgear, instrument transformers and relays are explained in detail. The close and trip, indication and alarm circuits for variety of Circuit breakers indicating ferrule numbers are also included. All relevant information and circuit diagrams necessary fro trouble shooting are also given.

We have more than 25 years experience, each in protective relaying and included a lot of information by way of original contribution apart from collection of useful information from a large number of reference books, manuals of manufacturers, etc. and it is hoped that this Hand Book will serve as a useful guide for all practicing Engineers.

We thank Sri M.Gopal Rao, Chief Engineer and Sri L.M.Sastry, Superintending Engineer, APTRANSCO for their valuable advise in preparation of this book. We also thank Sarvasri J. Dakshina Murthy & G. Seshagiri Rao, Divisional Engineers, M.Jagan Mohan Rao, Assistant Divisional Engineer & Mrs.Shilpa, Assistant Engineer of APTRANSCO, Sri V.R.Rao and Sri Diganta of PGCIL for patiently going through the Hand Book and for their valuable suggestions in bringing out this Book. Our special thanks to Sri M. Sreenivasa Reddy, J.P.O who has provided computer aided assistance in bringing out this Hand Book.

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PROTECTION

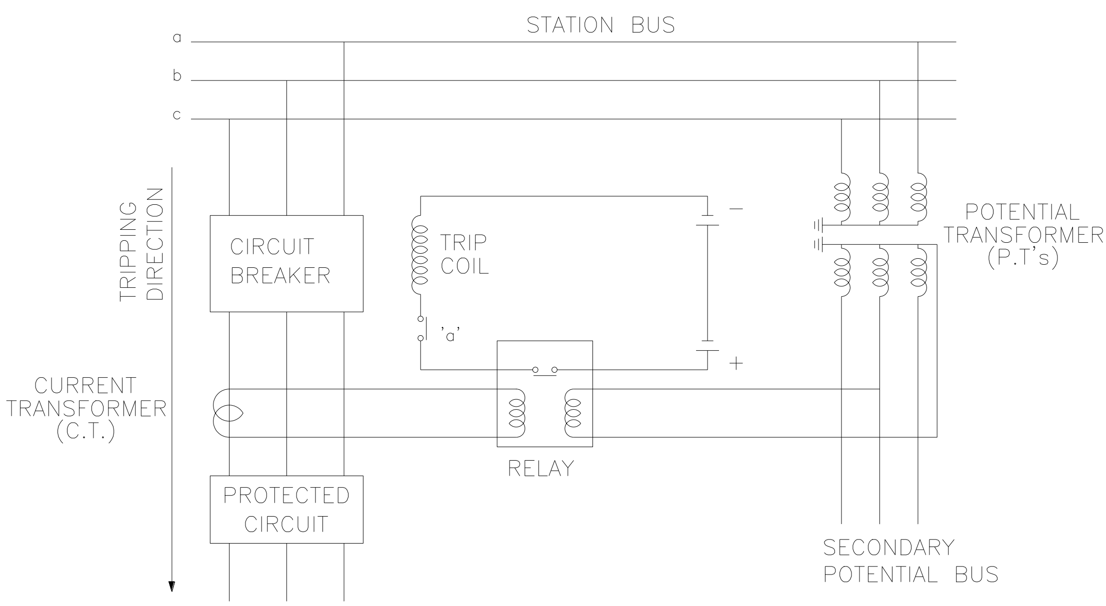
OBJECTIVE : To quickly isolate a faulty section from both ends so that the rest of the System can function satisfactorily.

IMPORTANT ELEMENTS :

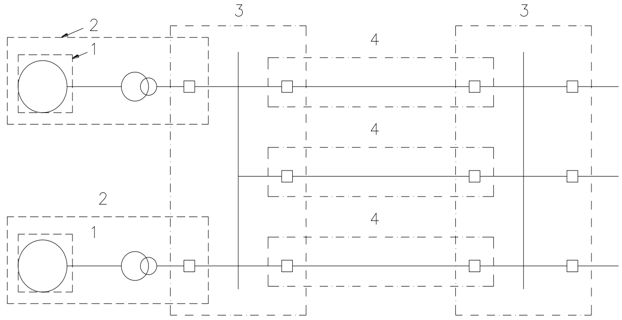
Switch gear: Circuit breaker Bulk oil, Minimum oil, SF6, Airblast, Vacuum etc. depending on medium used for quenching the arc. Different operating mechanisms such as solenoid, spring, pneumatic, hydraulic etc. are employed.

Protective gear: Relays (current, voltage, impedance, power, frequency, etc. based on operating parameter, definite time, inverse time, stepped etc. as per operating characteristic, logic wise such as differential, over fluxing etc.

Station Battery: A Station battery containing a number of cells accumulate energy during the period of availability of A.C supply and discharge at the time when relays operate so that relevant circuit breaker is tripped.

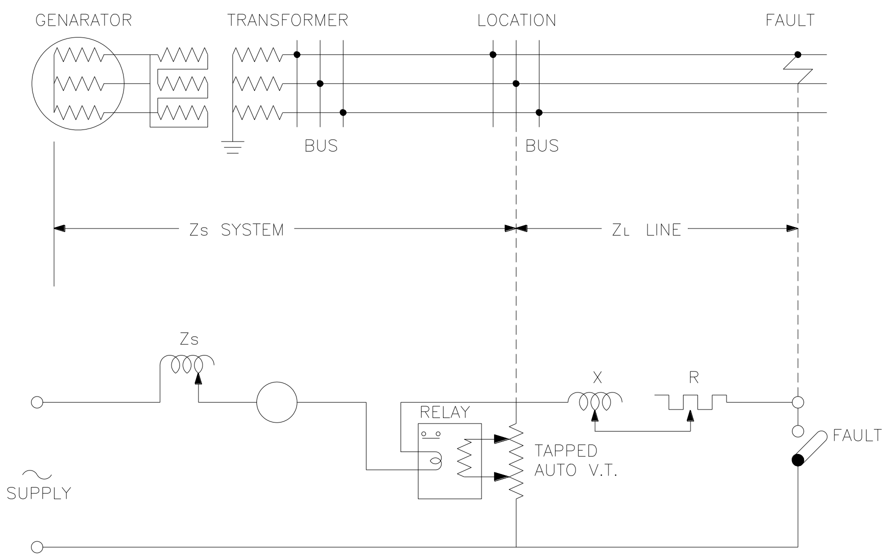


BASIC CONNECTIONS OF A PROTECTIVE RELAY



1. GENERATOR PROTECTIVE ZONE
2. GENERATOR TRANSFPRMER UNIT PROTACTIVE ZONE
3. BUSBAR PROTECTIVE ZONE
4. TRANSMISSION LINE PROTECTIVE ZONE

PROTECTIVE ZONES



TEST CIRCUIT EQUIVALENT OF POWER SYSTEM

CODE OF PRACTICE

CODE OF PRACTICE : PROTECTION

1.00 Circuitry

1.01 The entire wiring of circuitry for indications, alarms, metering and protection should be permanent wiring

1.02 There is no place for temporary wiring or adhocism in Relay circuitry

1.03 The leads should be identified by ferrules near terminals.

1.04 Every lead should end at a terminal point and no junctions by twisting is allowed. If two wires are to be terminated at same terminal they may be connected at two different terminals and a loop provided.

1.05 The wiring should be by copper leads for C.T secondaries for all cores (i.e.) metering as well as protection.

1.06 The wiring should be by copper leads for PT secondaries also wherever they are intended for protection.

1.07 The copper lead for 1.05 & 1.06 above should be stranded but not single lead type.

1.08 Aluminum leads can be used for indication, alarms and PT secondaries for metering but stranded wires only are to be used. However where PTs are employed for commercial metering, stranded copper wires are to be used.

1.09 The terminations should be lugged by ring shape ‘O’ lugs. ‘U’ shape lugs should be avoided.

1.10 For CT Secondary terminations, two nuts with one spring washer and two flat washers to be compulsorily used.

1.11 The terminal strips should be stud type with nuts and not screw-in-type.

1.12 Wherever two batteries are available, the primary protection and back-up protection should be from different batteries.

1.13 Where there is only one battery at a Power Substation, the primary and back-up protections should be given D.C supply through two individual circuits with independent fuses run from D.C bus.

1.13A When CBs have two trip coils, they may be connected for operation of primary and back-up protections separately.

1.14 D.C and A.C supplies should not be taken through different cores of the same cable.

1.15 Independent D.C cables should be run to every equipment in the yard and looping of D.C supply either in the yard or in the control room from one equipment to the other is not permitted.

1.16 The D.C yard lighting for emergency lighting should be through independent cables and not mixed up with protection and other circuitry.

1.17 For indications, alarms, annunciations, controls (closing coil, trip coil, etc. negative (-ve) is always given direct and positive (+ve) is supplied only ‘on commands’ like close, trip, relay trip, etc.

1.18 Where D.C protection supply is at 24 volts or 32 volts, the battery units should be very near the equipment and not in the control rooms.

1.19 In cases of 1.18 above, each tripping units (24 volts or 32 volts battery with charger) should not be used for more than two circuit breakers or equipment.

1.20 Standard colour codes for leads in control cable of different sizes should be as denoted on the cover page.

1.21 The lead numbers are also standardised as follows so that any MRT Engineer can easily identify the purpose for which the lead is connected by noting the lead number.

J Series	D.C Incoming	J1, J2, etc.
K Series	Control - Closing, Tripping, etc.	K1, K2, K3 etc.
L Series	Alarms, indications and annunciations	L1, L2, L3, etc.
E Series	Potential transformer secondaries	E1, E2, E3, etc.
H Series	LT A.C Supply	H1, H2, H3, etc.
A Series	C.T secondary for special protection	A1, A2, A3, etc.
B Series	Bus bar protection	B1, B2, B3, etc.
C Series	Protection Circuits	C1, C2, C3, etc.
D Series	Metering Circuits	D1, D2, D3, etc.

1.22 CTs with 1 amp secondary rating should be used compulsorily where meters, protective devices etc. are remotely situated with reference to equipment.

1.23 The CT ratios available and adopted with number of cores shall be displayed on each panel as follows: (with underlined position as adopted)

400 - <u>200</u> - 100 / 1-1-1

1.24 <u>Wherever CT cores are not used "SHORTING LOOPS" should be provided near CT secondary terminals and not in marshaling boxes or at panels</u>

1.25 The Cable entries near equipment, marshaling boxes and panels should be by use of appropriate size glands.

1.26 The Wiring inside the panels should be clear and neatly fastened avoiding loose wires.

1.27 All wires not in use should not only be disconnected but removed from panels.

1.28 PT secondaries should have group MOCBs with D.C alarm. Fuses at different panels should not be used.

1.29 Few cells from a battery of cells should not be used for separate low voltage D.C circuits. D.C - D.C converters only should be employed utilising full D.C voltage of the entire battery as input.

2.00 STANDARD LEAD NUMBERS

Certain lead numbers are standardised as follows and should be compulsorily adopted with ferrules at terminations of leads.

J1 - Positive
J2 - Negative

<u>Controls & Alarms</u>

Remote Close : K15R
Remote Trip : K5R
Local Close : K15L
Local Trip : K5L

Relay Family

Relay

Electro Magnetic | **Static** | **Mechanical**

Based on Characteristic

1. Definite time Relays
2. Inverse time Relays with definite minimum time (1 DMT)
3. Instantaneous Relays
4. IDMT with inst.
5. Stepped Characteristic
6. Programme Switches

Based on of logic

1. Differential
2. Unbalance
3. Neutral Displacement
4. Directional
5. Restricted Earth Fault
6. Over Fluxing
7. Distance Schemes
8. Bus bar Protection
9. Reverse Power Relays
10. Loss of excitation
11. Negative Phase Sequence Relays etc.

Mechanical

1. Thermal
(a) OT Trip
(b) WT Trip
(C) Bearing Temp Trip etc.
2. Float Type
(a) Buchholz
(b) OSR
(c) PRV
(d) Water level Controls etc.
3. Pressure Switches
4. Mechanical Interlocks
5. Pole discrepancy Relay

Based on actuating parameter

1. Current Relays
2. Voltage Relays
3. Frequency Relays
4. Power Relays etc.

Types of Control Panels

1	Control Panels
2	Relay Panels
3	Control & Relay Panels
4	Synchronising Panel or Trolley
5	Communication Panels
6	Annunciation Panels
7	D.C. dn. Board
8	A.C dn. Board
9	Charger Panels
10	Relay Galleries
11	Auxiliary Control Panels

12	Marshalling Boxes
13	AMG Panels
14	Machine Panels
15	Duplex(HV,LV) Panels
16	Bus Zone Protection Panels
17	RTC Panels (OLTC)
18	RTI Panels (temp)
19	Indoor Panels
20	Outdoor Panels
21	Panels with drawn up mimics & isolator cum breaker status indication (Semiphors) etc.

DEVICE NUMBERS AND THEIR NOMEMCLATURE

2	Time delay relay
3	Interlocking relay
21	Distance relay
25	Check synchronizing relay
27	Undervoltage relay
30	Annunciator relay
32	Directional power (Reverse power) relay
37	Low forward power relay
40	Field failure (loss of excitation) relay
46	Negative phase sequence relay
49	Machine or Transformer Thermal relay
50	Instantaneous Overcurrent relay
51	A.C IDMT overcurrent relay
52	Circuit breaker
52a	Circuit breaker Auxiliary switch “Normally open” (‘a’ contact)
52b	Circuit breaker Auxiliary switch “Normally closed” (‘b’ contact)
55	Power Factor relay
56	Field Application relay
59	Overvoltage relay
60	Voltage or current balance relay
64	Earth fault relay
67	Directional relay
68	Locking relay
74	Alarm relay
76	D.C Overcurrent relay
78	Phase angle measuring or out of step relay
79	AC Auto reclose relay
81	Frequency relay
81U	Underfrequency relay
81O	Overfrequency relay
83	Automatic selective control or transfer relay
85	Carrier or pilot wire receive relay
86	Tripping Relay
87	Differential relay
87G	Generator differential relay
87GT	Overall differential relay
87U	UAT differential relay
87NT	Restricted earth fault relay
95	Trip circuit supervision relay
99	Overflux relay
186A	Auto reclose lockout relay
186B	Auto reclose lockout relay

Over Current trip	}	
E/f. Trip	} Relay trip : K3 Master trip	
Diffl.Trip	}	
OSR/OLTC trip	:	163T
Bucholz trip	:	63T
O.T trip	:	26T
W.T trip	:	49T
Over fluxing trip	:	99
P.R.V trip	:	
Ter.Ala Trip	:	149T
Bucholz Alarm	:	63A
W.T Alarm	:	49A
O.T Alarm	:	26A
Ter.Alarm	:	149A
Busbar prot. Trip	:	96
Pole discrepancy trip	:	162
Indication +ve	:	L_1
OFF	:	L_3
ON	:	L_5
Semaphor OFF	:	L_7
Semaphor ON	:	L_9
C.B trip alarm	:	L_{21}
Bus A.B Switch remote OFF	:	L_{11}
Bus indication ON	:	L_{13}
Line/equipment-OFF	:	L_{15}
ON	:	L_{17}
ON	:	L_{19}
OFF	:	L_{21}

NORMS OF PROTECTION BEING FOLLOWED IN APTRANSCO

For Transmission & Distribution Lines

S.No.	Voltage	Protection Scheme
1.	400 KV Line	Main-I: Non switched or Numerical Distance Scheme Main-II: Non switched or Numerical Distance Scheme
2.	220 KV Line	Main-I : Non switched distance scheme (Fed from Bus PTs) Main-II: Switched distance scheme (Fed from line CVTs) With a changeover facility from bus PT to line CVT and vice-versa.
3.	132 KV lines	Main Protection : Switched distance scheme (fed from bus PT) Backup Protection: 3 Nos. directional IDMT O/L Relays and 1 No. directional IDMT E/L relay.
4.	33 KV lines	Non-directional IDMT 3 O/L and 1 E/L relays.
5.	11 KV lines	Non-directional IDMT 2 O/L and 1 E/L relays.

Notes

i. On some of the old 220KV lines one distance scheme with backup directional IDMT 3 O/L & E/L relays were provided.
ii. On some of the 132KV grid lines, only distance scheme is available
iii. Very few 66KV lines are in service (which are also being phased out)

Busbars : All 220 KV busbars will have busbar protection scheme with main and check zone

NORMS OF PROTECTION FOR EHV CLASS POWER TRANSFORMERS

Voltage ratio & capacity	HV Side	LV Side	Common relays
i. 132/33/11KV upto 8 MVA	3 O/L relays + 1 E/L relay	2 O/L relays + 1 E/L relay	Buchholz, OLTC Buchholz, OT, WT
ii. 132/33/11KV above 8 MVA and below 31.5 MVA	3 O/L relays + 1 dir. E/L relay	3 O/L relays + 1 E/L relay	Differential, Buchholz, OLTC Buchholz, OT, WT
iii. 132/33KV, 31.5 MVA & above	3 O/L relays + 1 dir. E/L relay	3 O/L relays + 1 E/L relay	Differential, Overflux, Buchholz, OLTC PRV, OT, WT
iv. 220/33 KV, 31.5MVA & 50MVA 220/132KV, 100 MVA	3 O/L relays + 1 dir. E/L relay	3 O/L relays + 1 dir. relay	Differential, Overflux, Buchholz, OLTC PRV, OT, WT
v. 400/220KV 315MVA	3 directional O/L relays (with dir.highset) +1 directional E/L relays. Restricted E/F relay + 3 Directional O/L relays for action	3 directional O/L relays (with dir.highset)+1 directional E/L relays. Restricted E/F relay	Differential, Overflux, Buchholz, OLTC PRV, OT, WT and overload (alarm) relay

Breaker failure protection: The LBB protection scheme will be provided for all 220KV stations (along with busbar protection scheme)

Transformers

i. No Buchholz relay for transformers below 500 KVA capacity
ii. Transformers upto 1500 KVA shall have only Horn gap protection
iii. Transformers above 1500 KVA and upto 8000 KVA of 33/11KV ratio shall have one group control breaker on HV side and individual LV breakers if there is more than one transformer. When there is only one transformer HV CB is necessary if the transformer is 3 MVA or above.
iv. Transformers above 8000 KVA shall have individual HV and LV circuit breakers.
v. The relays indicate above shall be provided on HV and LV
vi. LAs to be provided on HV & LV for transformers of all capacities and voltage class.
vii. OLTC out of step protection is to be provided where Master follower scheme is in operation
viii. Fans failure and pumps failure alarms to be connected.
ix. Alarms for O.T., W.T., Buchholz (Main tank & OLTC) should be connected.

Points to be checked while drawing CTs

1. Voltage class
2. Indoor /Outdoor
3. Oil filled?Resin cast? Ring type?
4. Short Circuit rating
5. Available ratios
6. Secondary Current values
7. Available cores
8. Burden
9. Class of Accuracy
10. Terminal Connections
11. Over all dimensions

    etc.

Points to be verified while drawing Circuit Breakers

1. Voltage class
2. Indoor /Outdoor
3. Quencing : Bulk oil or Min. Oil or SF6 or Vacuum or Air blast
4. D.C Control voltage or 24V or 32V or 110V or 220V
5. Rated current (make & break)
6. Rupturing capacity
7. Operating mechanism : Spring? Solenoid? Pneumatic? Hydraulic? Air blast?
8. Terminal connections
9. Overall dimensions
10. Details of CTs if provided with breaker
11. Protective devices along with breaker
12. Details of PT, etc. if provided with breaker etc.
13. Trip/Break time, closing time limit

C.T. RATIOS AND RELAY SETTINGS TO BE ADOPTED

- The C.T ratios and relay settings for all equipment at EHT substation upto L.V breakers of Power transformers shall be approved by SE/System Protection.
- The C.T ratios and relay settings for all 33KV & 11KV feeder breakers at EHT substations shall be approved by DE / MRT / TL & SS. The CT Ratios and relay settings for all breakers at 33/11KV substations shall be approved by DE(M & P) concerned.
- The relay settings so approved by SE/System Protection or the concerned DE shall not be altered by any other officer.
- The officers above are responsible for relay Co-ordination and gradation.
- If a 33KV feeder feeds more than one substation and they fall in the jurisdiction of two different DEs(M & P), the DE(M & P) i/c of substations first feed will communicate the relay settings to the other DE/M & P who have to ensure coordination.
- Where 33KV, 66KV, 132KV and 220KV HT consumers are fed through lines, the DEs(Opn.) have to collect details of lay-out, switch gear and relays available and furnish to DE(MRT) in respect of 33KV and SE/System Protection for EHT and obtain approved relay settings and ensure their adoption by the HT consumers. No variation in the approved settings shall be allowed without written approval of DE(MRT) or SE/System Protection as the case may be.

LIMITS OF ERRORS IN CTs

Class0.1to1.0: The Current Error and phase displacement Error at the rated frequency shall not exceed the values given below when the secondary burden is any value from 25% to 100% to the rated burden.

% of error at % of rated Current					Phase displacement in minutes at % of r.ct			
Class	**10**	**20**	**100**	**120**	**10**	**20**	**100**	**120**
0.1	±0.25	±0.20	±0.10	±0.1	±10	±8	±5	±5
0.2	±0.50	±0.35	±0.20	±0.2	±20	±15	±10	±10
0.5	±1.00	±0.75	±0.75	±0.5	±60	±45	±30	±30
1.0	±2.00	±1.50	±1.50	±1.0	±120	±90	±60	±60

Class 3&5	50%	100%
3	±3	±3
5	±5	±5

	IS	BS
Precession Metering	0.1or 0.2	BL BL
Comml. or Indl.metering	0.5 or 1.0	AM BM CM
Ammeters, power meter	1.0 or 3.0	CD
Relays	$5P_{10}$ or $5P_{20}$	STU
Selective protection	PS	

Composite Error for Protection ISS 2705 Part.III

Accuracy Class	Current error at rated prim. current	Phase displacement at rated prim current +Min.	Composite error at rated prim. current +
5 P	1	60	5
10 P	3	-	10
15 P	5	-	15

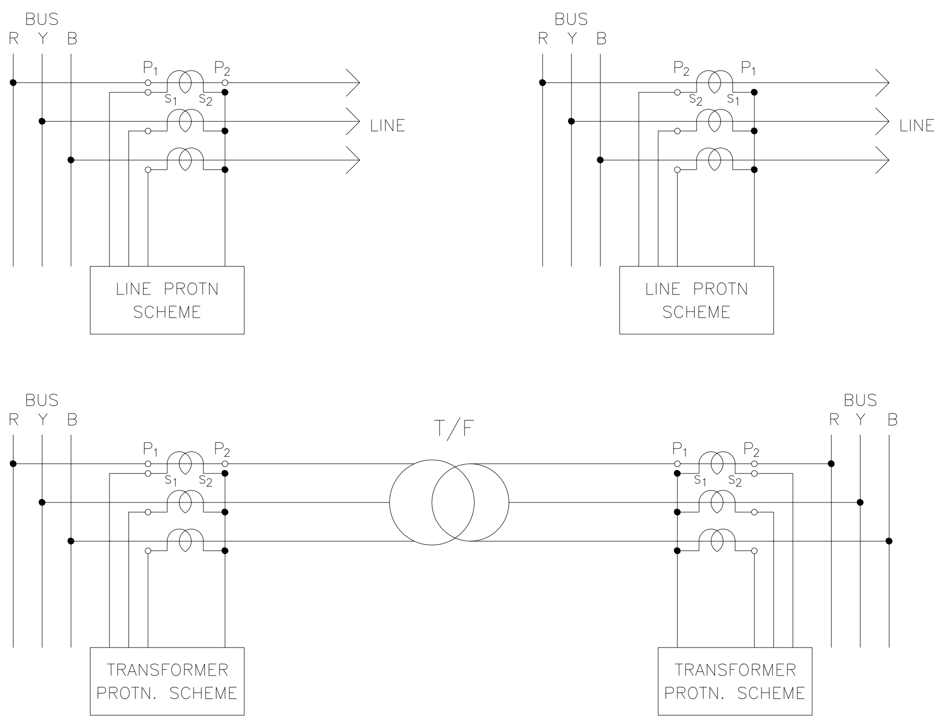
C.T. SECONDARY CONNECTIONS

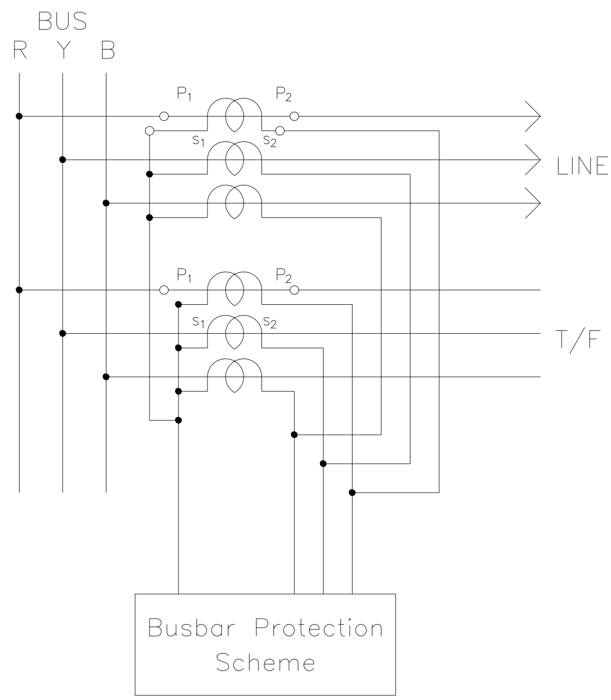
For protection of various equipment of EHT class, the Star point on secondaries of CT should be made as follows for ensuring correct directional sensitivity of the protection scheme

1. For Transmission Lines - Line side
2. For Transformers - Transformer side
3. For Bus bar - Bus side

The above method has to be followed irrespective of polarity of CTs on primary side. For example, in line protection, if ‘P1’ is towards bus then ‘S2’s are to be shorted and if ‘ P2’ is towards bus then ‘S1’s are to be shorted.

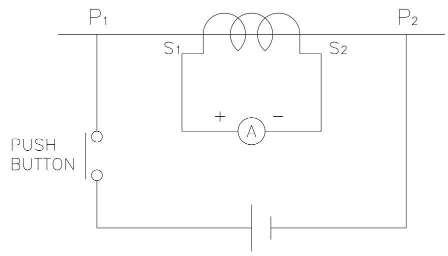
The C.T secondary connections for Transmission line, Transformer and Busbar are indicated in the figures.




BUS
R Y B
P1
P2
S1
S2
LINE
P1
P2
S1
S2
T/F
Busbar Protection
Scheme

C.T POLARITY TEST

Each current transformer should be individually tested to verify that the polarity markings on the primary and secondary windings are correct. The following figure shows the test unit for this.

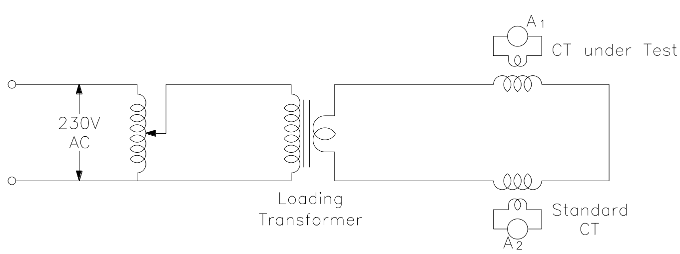


The ammemeter ‘A’ is a robust, moving coil, permanent magnet centre zero type instrument. A low voltage battery is used to energise the primary windings through a single pole push button. On closing the push-button, with above C.T ammeter markings, the ammeter should give a positive flick, indicating correct polarity of the C.T

PRIMARY INJECTION TEST

This test is carried out to ensure the C.T ratio of current transformers. If this test is carried out after C.T secondary wiring is completed it ensures not only the correct ratio of C.Ts but also the correctness of the entire C.T secondary wiring comprising protection and metering portions. The testing equipment consists of a loading (injection) transformer, controlled by a variable transformer to get the required current on the primary side of the C.T under test.

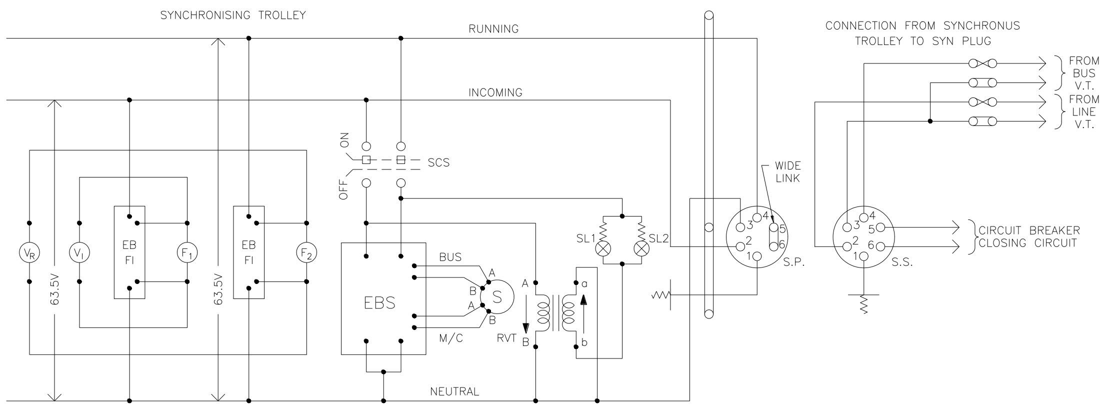
For carrying out the ratio test on C.Ts, the following circuit is made use of.



Current is passed through the primary windings of the standard C.T and C.T under test. The ratio of the C.T can be determined by comparing the currents in ammeters A1 and A2.

VOLTAGE TRANSFORMERS

Class of Accuracy	Application	LIMITS OF ERROR			
		At 90% to 100% of rated burden & 80 to 100% of rated burden UPG		At 90-100% of burden 10 to PF Ph.displace-ment	
		Ratio	Ph.displa ce-ment	Ratio	
A	Sub-standard Indication meters	0.5	20	0.5	20
B	1st grade indicating inputs watt meter, Indl & Synchronising	1.0	30	1.0	70
C	1st grade voltmeter	2.0	60	-	-
D	Where ratio is of less importance A, B & C not required	5.0	-	-	-



RGF.	DESCRIPTION
VR	VOLT METER (RUNNING)
VI	VOLT METER (INCOMING)
EB FI	EXTERNAL BOX FOR FREQUENCY METER (INCOMING)
EB FR	EXTERNAL BOX FOR FREQUENCY METER (RUNNING)
FI, FR	FREQUENCY METERS (INCOMING; RUNNING)
EBS	EXTERNAL BOX FOR SYNCHROSCOPE
RVT	REVERSING VOLTAGE TRANSFORMER
SL1 & SL2	INDICATING LAMPS (SYNCHRONISING)
S.P.	SYNCHRONISING PLUG
S.S.	SYNCHRONISING SOCKET
SCS	SYNCHROSCOPE CUT-OFF SWITCH

220 KV SYNCHRONISING SCHEME

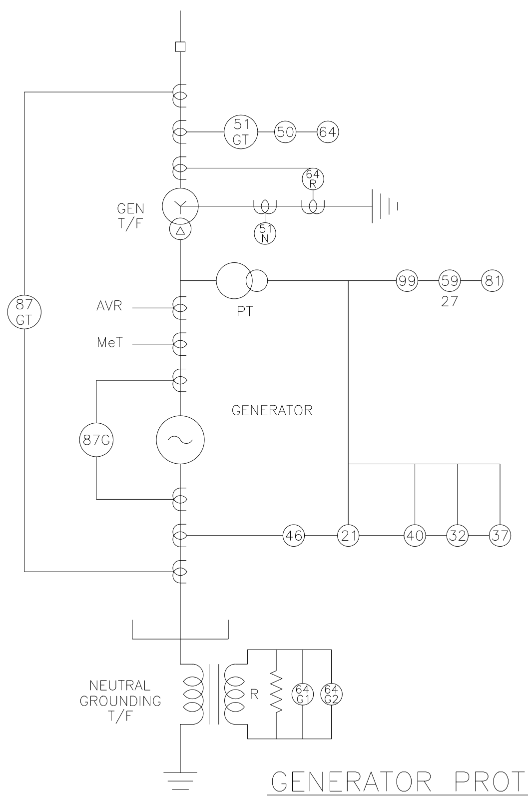
PERIODICAL TESTINGS

1. The relays should be tested
    a) Annually
    b) Whenever time lever settings are altered.
    c) Whenever mal-operation of relay is suspected
    d) Whenever directed by DE/M & P Concerned
    e) Whenever directed by CE / Power System or SE / System Protection / Vidyut Soudha / Hyderabad.
2. It is the responsibility of Asst.Divisional Engineer (Protection to maintain a Calendar and ensure testing of relays)
3. The Asst.Engineer (Protection) is responsible for the accuracy of test results noted in the Test Record.
4. Breaker opening and closing times should be checked.
    a) at the time of commissioning
    b) annually during service
    c) Whenever trip or closing coils are changed
    d) Whenever major repairs to operating mechanism are done
    e) Whenever breaker contacts are changed.
5. Station earth resistance of earth pits and combined value should be taken
    a) annually
    b) Whenever directed by DE(MRT)
6. The Assistant Divisional Engineer (Maintenance) in charge of the Substation is responsible for measurement and record of Substation earth resistances and carrying out improvements where necessary.

GENERATOR AND ITS PROTECTION

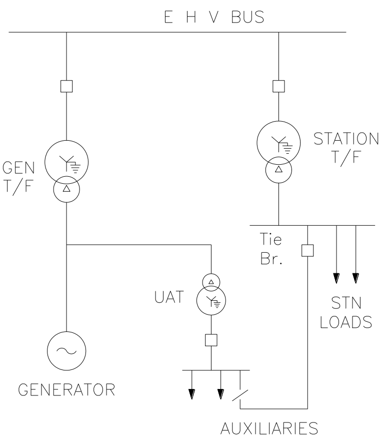
The core of an electrical power system is the generator. There are power units based on steam, gas, naphtha, water power, diesel engine drive and wind mills. The range of size extends from a few hundred KVA (or even less) for engine-driven and hydro sets up to turbine driven sets exceeding 500MVA in rating.

Small and medium sized sets may be directly connected to the distribution system. A larger unit is usually associated with an individual transformer, transmission system. No switchgear is provided between the generator and transformer may be tapped off the interconnection for the supply of power to auxiliary plant. Provision of a breaker in between Generator and Transformer makes it possible to draw power for the auxiliaries through the UAT from the EHV bus, even when machine is not in service. Typical arrangements are given in figure............

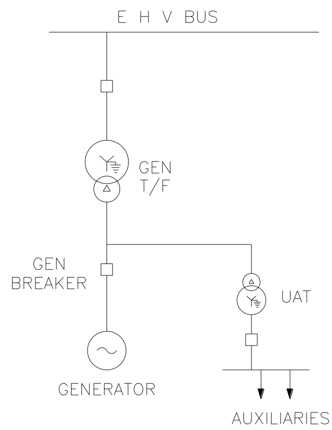


GENERATOR PROTECTION SCHEME

GENERAL LAY-OUT OF GENERATING STATIONS



GENERATOR & GEN. T/F. AS A UNIT



UNIT WITH GENERATOR BREAKER

Generator Protection – Various Functions

Generating units are the source of the power system and their security against any adverse conditions is most important in the system. The generator protection must ensure a fast and selective detection of any fault in order to minimize their dangerous effects.

Protection of passive elements like transmission lines and transformers is relatively simple which involves isolation of faulty element from the system, whereas protection of generators involves tripping of generator field breaker, generator breaker and turbine.

Generator Protections are broadly classified into three types.

CLASS – A :- This covers all electrical protections for faults within the generating unit in which generator field breaker, generator breaker and turbine should be tripped.

CLASS – B:- this covers all mechanical protections of the turbine in which turbine will be tripped first and following this generator will trip on reverse power / low forward power protections.

CLASS – C:- This covers electrical protection for faults in the system in which generator will be unloaded by tripping of generator breaker only. The unit will come to house load operation and the UAT will be in service. Various protections of this class are:

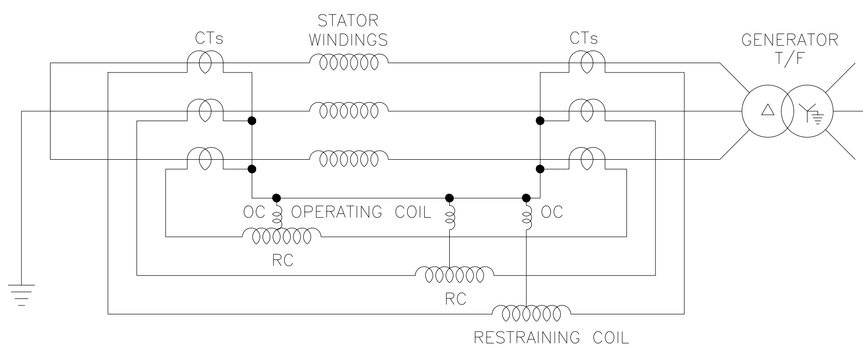
- i) 220 KV (HV side of Generator Transformer) busbar protection.
- ii) Generator Transformer HV side breaker pole discrepancy.
- iii) Generator negative phase sequence protection
- iv) Generator Transformer over current / Earth fault protection
- v) Reverse power protection without turbine trip.

1) **Generator Differential Protection (87 G): -**

It is unit type protection, covering the stator winding for phase to phase faults due to breakdown of insulation between stator phase windings. This relay is not sensitive for single line to earth faults as the earth fault current is limited due to the high neutral earthing resistance.

If CTs of identical ratios are used on neutral and line side of generator, an operating current setting of 20% it can be adopted. It is instantaneous in operation and it trips the generator breaker (Class – A) to eliminate the system in – feed to the fault along with field breaker and turbines.

For all machines of ratings 10 MVA and above, this protection shall be provided.



GENERATOR DIFFERENTIAL RELAY

2) **Generator – Transformer Differential Protection (87GT):-**

This is similar to Generator Differential Protection, which covers from the generator terminals upto the HV breaker of generator transformer. It will detect phase faults on both sides of generator transformer and single phase to phase to earth faults on HV side only.

87G & 87GT functions should have the features of through fault restraint, magnetising inrush restraint.

3) **Backup impedance Protection (21G):-**

This operates for phase faults in the unit, in the HV yard or in the adjacent transmission lines, with a suitable time delay. It operates as a backup when the corresponding main protection fails.

It can be set to cover the longest outgoing line. In A.P. System the reach is set as 120% of generator transformer with a time delay of about 1.0 to 1.5 Sec.

4) **<u>Voltage restrained overcurrent protection (51 / 27 G):-</u>**

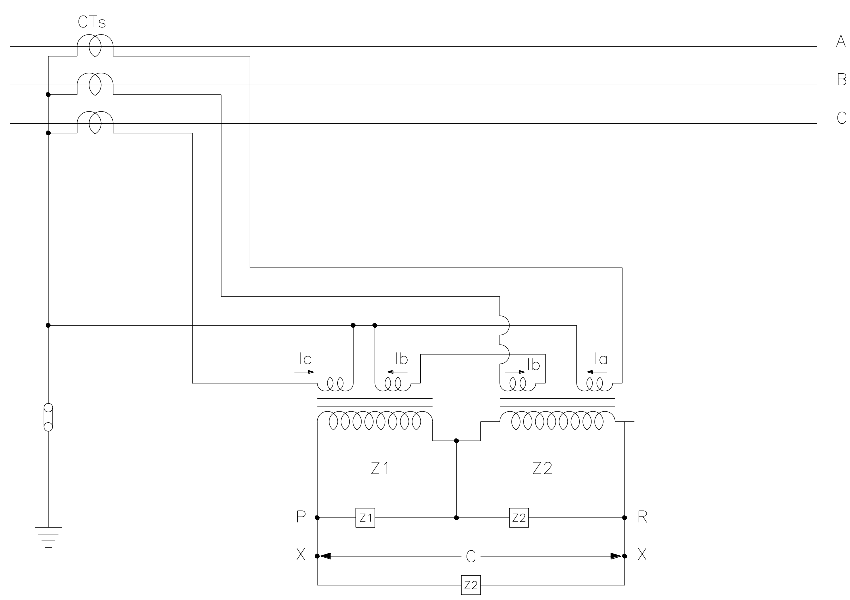
This will operate when the fault current from the generator terminals becomes low due to excitation system characteristic with under voltage criteria.

It operates as a backup protection for system faults with suitable time delay.

5) **<u>Negative phase sequence protection (46 G):-</u>**

It safeguards the generator rotor against over heating caused by the induced double frequency (100 Hz) currents when negative phase sequence currents are present in the stator. The negative phase sequence current can appear due to unbalanced single phase loads or transmission line unsymmetrical faults.

It should be set according the NPs capability of the generator. Alarm stage can be set at 50% of continuous withstand capability of the machine with a time delay of 3 to 5 Sec.



NEGATIVE PHASE SEQUENCE CIRCUIT AGAINST

6) **Generator overloads protection (51G);-**

It is used as an additional check of the stator winding temperature high protection. It will be connected for alarm in Hydro units only.

7) **Generator Stator Earth Fault Protection (64G):-**

The high neutral earthing resistance arrangement limits the generator earth fault current, minimising the damage to core laminations. Although a single phase earth fault is not critical, it requires clearance within a short time due to:

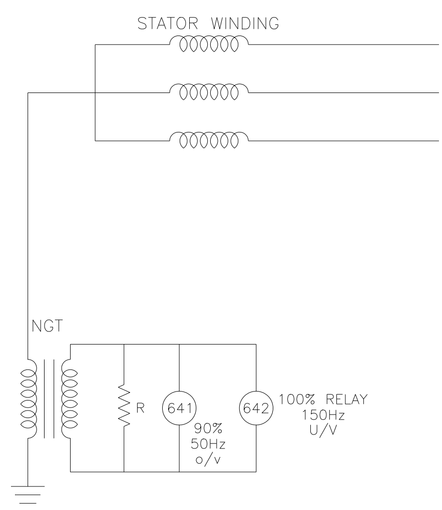
i) It may develop into a phase to phase fault

ii) If a second earth fault occurs the current is not longer limited by the earthing resistor.

iii) Fire may result from earth fault arc.

a) **95% stator earth fault protection (64G1):-**

It is an over voltage relay monitoring the voltage developed across the secondary of the neutral grounding transformer in case of ground faults. It covers generator, LV winding of generator transformer and HV winding of UAT. A pickup voltage setting of 5% is adopted with a time delay setting of about 1.0 Sec. For all machines of ratings 10 MVA and above this shall be provided.



STATOR EARTH–FAULT RELAY

b) **100% stator earth fault protection (64G2);-**

This is a 3rd harmonic U/V relay. It protects 100% of stator winding. It is based on reduction of 3rd harmonic voltage caused by an earth fault. This shall have voltage check or current check unit, to prevent faulty operation of the relay at generator stand still or during the machine running down period.

8) **Loss of Excitation (40G):-**

In case of loss of excitation, the generator goes out of synchronism and starts running asynchronously at a speed higher than the system, absorbing reactive power from the system. Under these conditions, the stator end regions and part of the rotor get over heated.

This protection shall have:

i) Mho characteristic lying in 3rd and 4th quadrants of impedance diagram with adjustable reach and offset.

ii) An under voltage and / or overcurrent relay as additional check.

iii) A timer with adjustable range of 1-10 Sseconds.

Recommended Settings:-

- Diameter of Mho circle	=Xd
- Off set of Mho circuit from the origin	= xd $^{1}/_{2}$
- Time delay	= 1 Sec.
- Under voltage relay	= 110 – 115% of generator rated current

9) **Low Forward Power Relay (37G):-**

In thermal machines, when the steam flow through turbine is interrupted by closing the ESVs or the governor valves, the remaining steam in the turbine generates (low) power and the machine enters to motoring conditions drawing power from the system. This protection detects low forward power conditions of the generator and trips generator breaker after a time delay, avoiding motoring of generator.

The low forward power relay will be provided with ‘turbine trip’ interlock in thermal machines. A setting of 0.5% of rated active power of generator with a time delay of 2.0 Sec. shall be adopted.

10) **Reverse Power relay (32G):-**

Reverse power protection shall be used for all types of generators. When the input to the turbine is interrupted the machine enters into motoring condition drawing power from the system. Reverse power relay protects the generators from motoring condition. In thermal machines, reverse power condition appears subsequent to low forward power condition.

For reverse power relay, a setting of 0.5% of rated active power of generator with 2 stage timer as given below.

i) **<u>Stage – I: -</u>** With turbine trip interlock, a time delay of 2 Sec. shall be adopted.

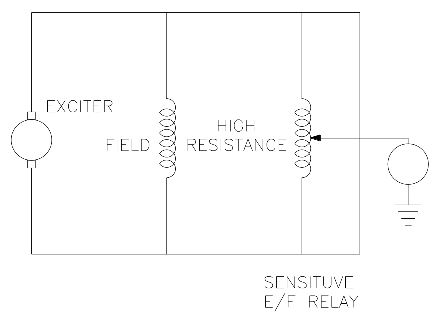
ii) **<u>Stage – II:-</u>** Without ' turbine trip' interlock, a time delay of about 20 Sec. can be adopted to avoid unnecessary tripping of unit during system disturbance causing sudden rise in frequency or power swing conditions.

11) **<u>Rotor earth fault protection: -</u>**

This protection shall be provided for machines of all sizes. This protection shall be connected for alarm and the operator may take the machine at the earliest opportunity after the first earth fault has occurred.

This protection will have a sensitive voltage function operating on bridge measurement basis with auxiliary equipment. It will have two levels, one for alarm and one for trip. The settings adopted in general are:

i)	For alarm	:	25 KJ Ohm, 1.0 Sec.
ii)	For trip	:	5 K Ohm, 5 Sec.



ROTOR EARTH—FAULT RELAY

A modern generating unit is a complex system comprising the generator stator winding and associated transformer and unit transformer, the rotor with its field winding and exciters, and the turbine and its associated condenser and boiler complete with auxiliary fans and pumps. Faults of many kinds can occur within this system for which diverse protection applied will be governed by economic considerations, taking into account the value of the machine and its importance to the power system as a whole.

The following hazards require consideration.

a) Stator insulation faults
b) Overload
c) Overvoltage
d) Unbalanced loading
e) Rotor faults
f) Loss of excitation
g) Loss of synchronism
h) Failure of prime mover
i) Low vacuum
j) Lubrication oil failure
k) Loss of boiler firing
l) Overspeeding
m) Rotor distortion
n) Difference in expansion between rotating and stationary parts
o) Excessive vibration

Small capacity induction generators also are in service, mostly mini hydel and windmills of capacity of 200KW to 2000KW, which depend on the system for excitation. Their protection requirements are very simple such as overcurrent relays.

The protective relays generally used for the synchronous generators are listed at in the following page.

Instead of independent relays for each function, microprocessor based numerical relay, which can take care of the entire Generator protections the latest entry.

Functions	**Steam**	**Gas**	**Turbines**	**Hydro**	**Turbines**	
	Small (<10 MVA)	**Medium (10-100 MVA)**	**Large (>100 MVA)**	**Small (<10 MVA)**	**Medium (10-100 MVA)**	**Large (>100 MVA)**
Differential	Y	Y	Y	Y	Y	Y
95% Stator E/F	Y	Y	Y	Y	Y	Y
100% Stator E/F	N	Y/N	Y	N	Y/N	Y
Interturn Faults	Y	Y	Y	Y	Y	Y
Backup Impedance	N	Y	Y	N	Y	Y
Voltage controlled O/C	Y	N	N	Y	N	N
Negative Sequence	Y	Y	Y	Y	Y	Y
Field Failure	Y	Y	Y	Y	Y	Y
Reverse Power	Y	Y	Y	Y	Y	Y
Pole Slipping	N	N	Y	N	N	Y
Overload	N	N	N	Y	Y	Y
Over voltage	Y	Y	Y	Y	Y	Y
Under frequency	Y	Y	Y	Y	Y	Y
Dead machine	N	N	Y	N	N	Y
Rotor Earth Fault	Y	Y	Y	Y	Y	Y
Overfluxing	N	Y	Y	N	Y	Y

TRANSFORMER PROTECTION

TRANSFORMER PROTECTION

The rating of Power transformers used in A.P System.

1. 400/220 KV 315 MVA Auto Transformers
2. 220/132 KV 100MVA Auto Transformers
3. 220/33 KV 50 & 31.5MVA Transformers
4. 132/66 KV 40 & 27.5MVA Transformers
5. 132/33 KV 50, 31.5, 25, 16, 15 MVA Transformers
6. 132/11 KV 16, 15 & 7.5 MVA Transformers
7. 33/11 KV 8, 5, 3.15 MVA Transformers

Most of the Power transformers of 132/11KV and above are of Star-Star vector grouping with the neutral solidly earthed. There are a few transformers with delta-star (delta on HV side). The 33/11KV and 11KV/415V Transformers are of delta-star (delta on HV side).

The types of faults that the transformers are subjected to are classified as:-

1) Through Faults:- These are due to overload conditions and external short circuits.

Time graded O/C & E/F relays are employed for external short circuit conditions. Fuses are provided for Distribution transformers.

2) Internal Faults:-

a) Electrical Faults: - Faults which cause immediate serious damage such as phase to earth or phase to phase faults, short circuits between turns of HV&LV windings, etc.

b) Incipient Faults: - Which are initially minor faults, causing slowly developing damage. Such as a poor electrical connection of conductors of breakdown of insulation, etc.

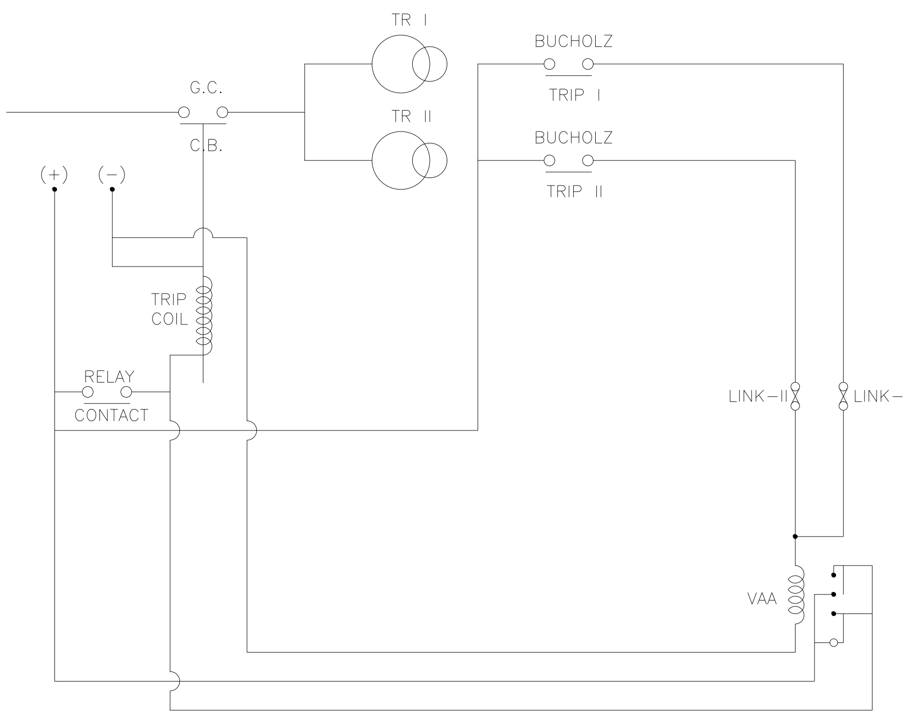
The following relays are employed to protect the transformer against internal faults.

i) Buchholz relays
ii) Differential relays
iii) REF relays.
iv) Overfluxing relays

i) Buchholz Relays: - Whenever a fault in a transformer develops slowly, heat is produced locally, which begins to decompose solid of liquid insulating materials and thus to produce inflammable gas and oil flow. This relay is applicable only to the conservator type transformers. Buchholz relay is connected in the pipe leading to the conservator tank and detect the gas produced in the transformer tank.

Precaution: -

The Buchholz relay may become operative due to entrapped air accumulated when oil is added to a transformer.



BUCHOLZ TRIP CONNECTIONS FOR POWER TRANSFORMER

ii) Differential Relays

1. Two basic requirements that the differential relay connections are to be satisfied are:
   a) It must not operate for load or external faults.
   b) It must operate for internal faults.

2. The current flowing through the operating coil of the relay should be nearly zero during normal operating conditions and when external short circuit occurs.

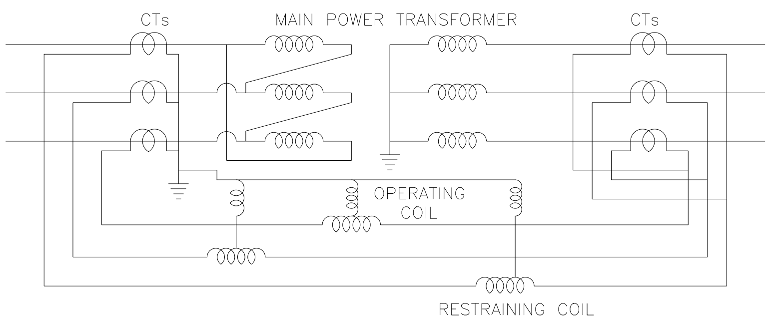
C.T Ratios and connections for differential relay

1. A simple rule of thumb is that the CTs on any Wye (Star) winding of a Power transformer should be connected in delta and the CTs on any delta winding should be connected in Wye (Star).

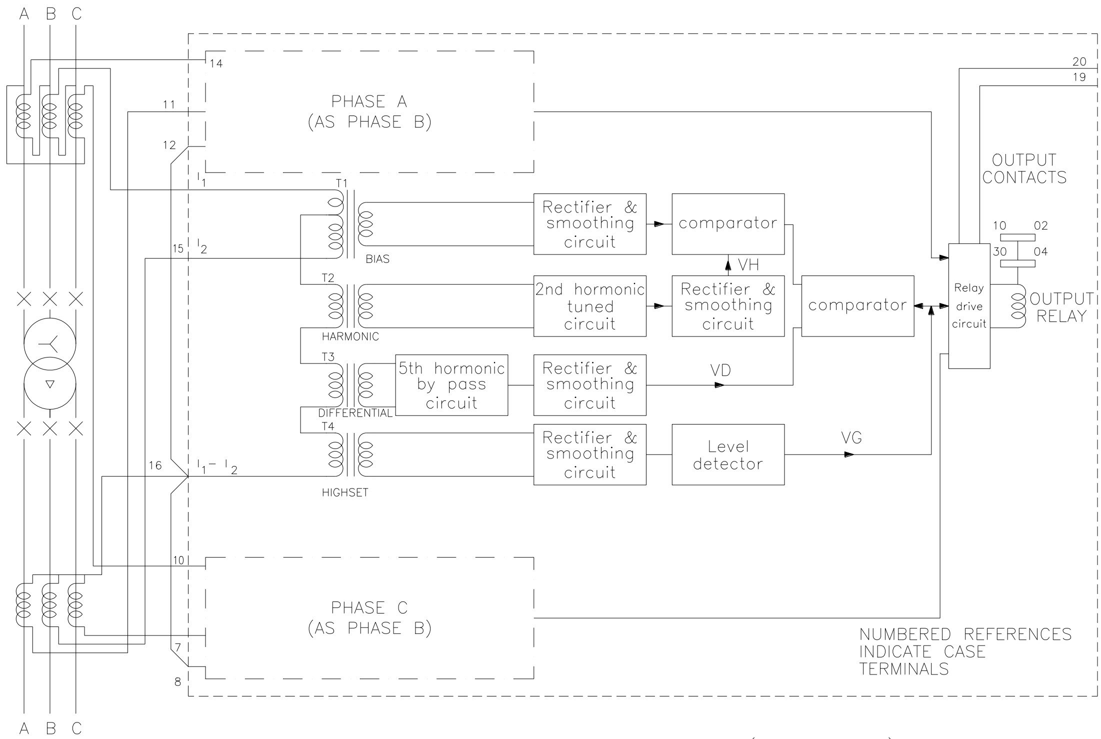
2. a) If the CTs are to be connected in Star, the C.T Ratio will be In/1A

   Where In is transformer full load current.

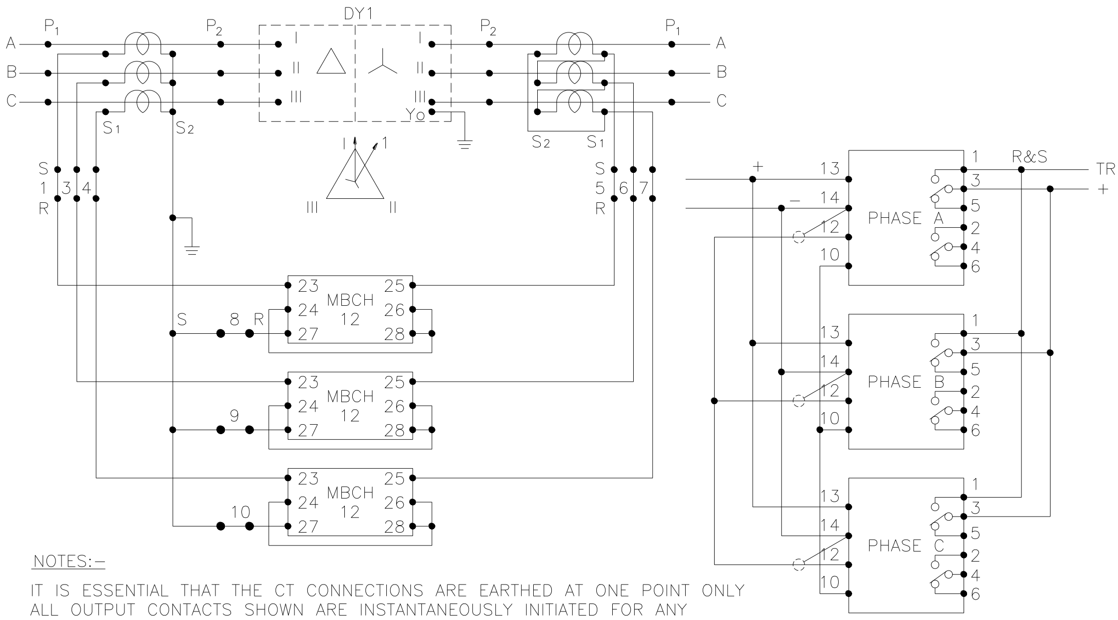
b) If the CTs are to be connected in Delta, the C.T Ratio will be In/0.5775 A.



DIFFERENTIAL RELAY CONNECTIONS FOR A DELTA–STAR TRANSFORMER



BLOCK SCHEMATIC DIAGRAM OF DTH31 (EE MAKE)



NOTES:–

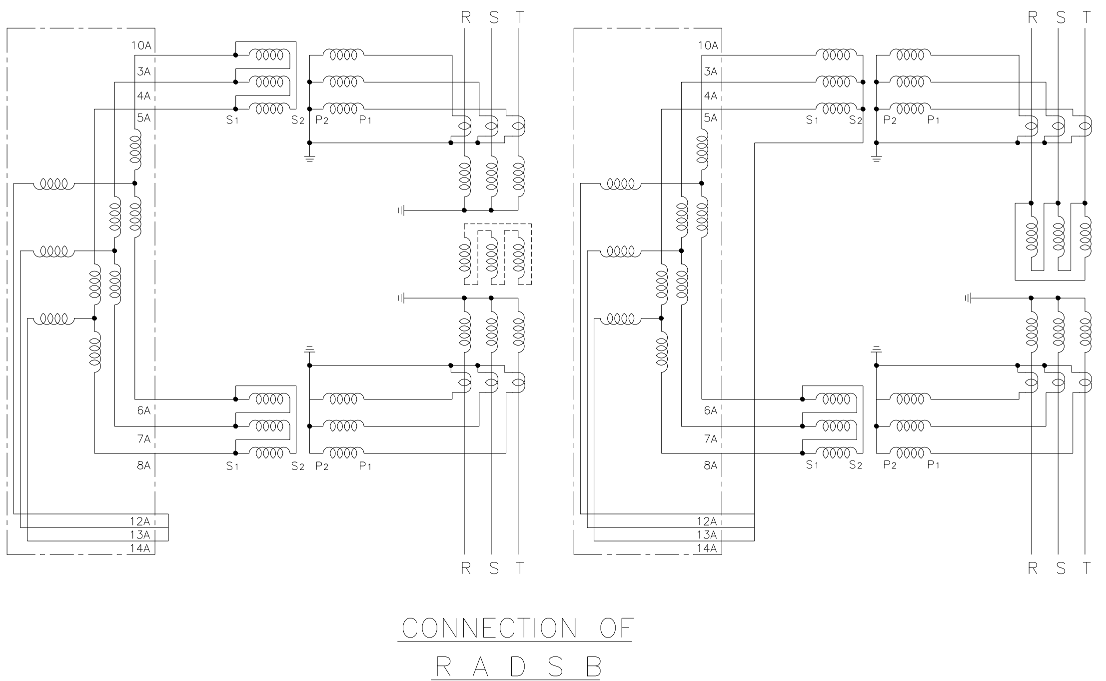
IT IS ESSENTIAL THAT THE CT CONNECTIONS ARE EARTHED AT ONE POINT ONLY

ALL OUTPUT CONTACTS SHOWN ARE INSTANTANEOUSLY INITIATED FOR ANY INTERNAL FAULT CONDITION WHEN TERMINALS NO.10 ON EACH PHASE UNIT ARE CONNECTED TOGETHER AS SHOWN CORRECT PHASE INDICATION IS MAINTAINED.

TERMINAL 12 ON EACH PHASE ASSEMBLY SHOULD BE INTERCONNECTED BY A SCREENED LEAD RGJ0153 001 WITH THE SCREEN CONNECTED TO TERMINAL 14.

THE RELAY CONNECTIONS ARE TO BE ROUTED THROUGH TEST BLOCK TYPE MPG FOR TESTING PURPOSES. THE WAYS OF MPG TEST BLOCK ARE SHOWN BY THE SYMBOL •—•

TYPICAL APPLICATION DIAGRAM OF MBCH 12



CONNECTION OF

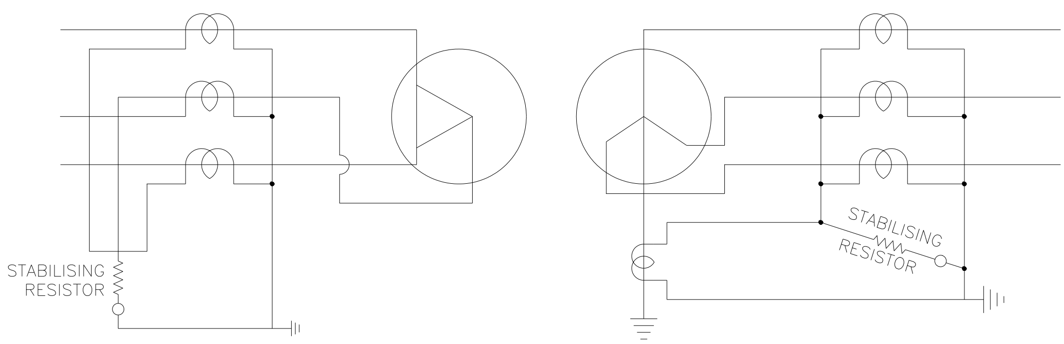
R A D S B

Restricted Earth Fault Protection (REF): -

This relay is operative only for the internal faults of the transformer and thus fast operating timer can be achieved.

1. An external fault on the star side will result in current flowing in the line CT of the affected phase and a balancing current in the neutral CT and current in the relay is zero and hence relay is stable. During an internal fault, the line current on the line CT gets reversed and hence relay operates.

2. The arrangement of residually connected CTs on the delta side of a transformer is only sensitive to earth faults on the delta side because zero sequence currents are blocked by the delta winding.



RESTRICTED EARTH FAULT PROTECTION OF TRANSFORMER

Overfluxing Protection

1. Overfluxing condition in a transformer can occur during system over voltage and/or under frequency conditions (V/F).

2. The Overfluxing condition does not call for high speed tripping. The tripping can be delayed depending on the overflux withstand capability of the transformer.

3. Relays with definite time delay (nearly 30Sec.) and inverse characteristic are being employed.

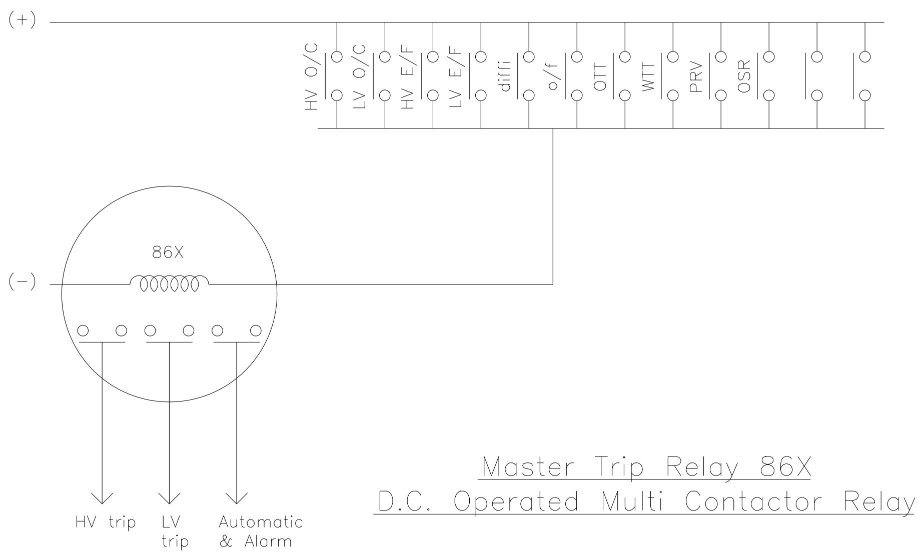
<u>Other Protective devices employed</u>

Pressure Relief Value (PRV)

Winding Temperature

Oil Temperature

OLTC Buchholz



TRANSMISSION LINES PROTECTION

Transmission Line Protection

Distance Relays: -

Introduction:

The impedance relays also called distance relays are employed to provide protection to transmission lines connected in a network as they are economic and possess several technical advantages. They are comparatively simple to apply, operate with extremely high speed, and both primary and backup protection features are inherent in them. Moreover, they can be easily modified to work as unit schemes by coordinating them with power line carrier facilities and are suitable for high speed reclosing. The impedance relay is made to respond to the impedance between the relay location and the point where fault is incident. The impedance is proportional to the distance to the fault, (hence the name 'distance relay') and is therefore independent of the fault current levels.

Distance Relaying Principle:

A distance relay compares the currents and voltages at the relaying point with Current providing the operating torque and the voltage provides the restraining torque. In other words an impedance relay is a voltage restrained overcurrent relay.

The equation at the balance point in a simple impedance relay is $K_1V^2 = K_2I^2$ or $V/I = K_3$ where K_1, K_2 and K_3 are constants. In other words, the relay is on the verge of operation at a constant value of V/I ratio, which may be expressed as an impedance.

Since the operating characteristics of the relay depend upon the ratio of voltage and current and the phase angle between them, their characteristics can be best represented on an R-X diagram where both V/I ratio and the phase angle can be plotted in terms of an impedance R+jX. Further, the power system impedance like fault impedance, power swings, loads etc. can also be plotted on the same R-X diagram. Therefore response of a particular relay during power swing, faults and other system disturbances can easily be assessed.

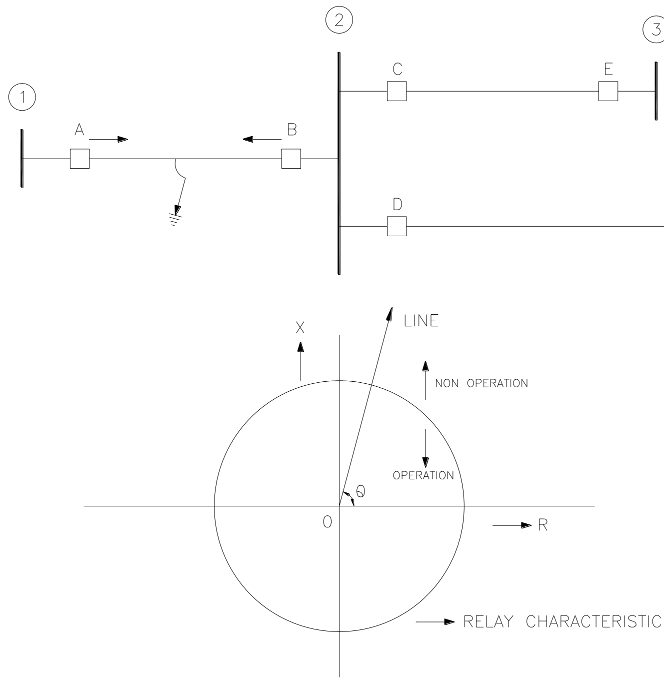
Types of Distance Relays:

(1) Impedance relay
(2) Reactance relay
(3) Mho relay
(4) Modified impedance relay

(1) <u>Impedance relay:</u>

Characteristics of an impedance relay on R-X diagram is shown in fig

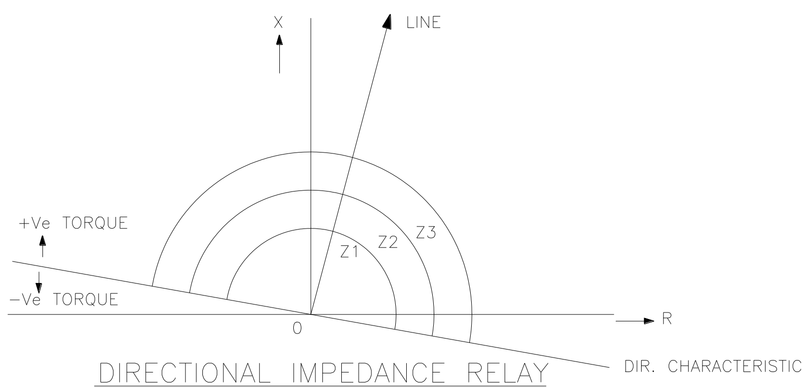
Operation of the impedance relay is independent of the phase angle between V and I. The operating characteristic is a circle with its center at the origin, and hence the relay is non-directional.



IMPEDANCE RELAY

<u>Characteristic of Directional Impedance Relay:</u>

Characteristic of a directional impedance relay in the complex R-X phase is shown in fig.

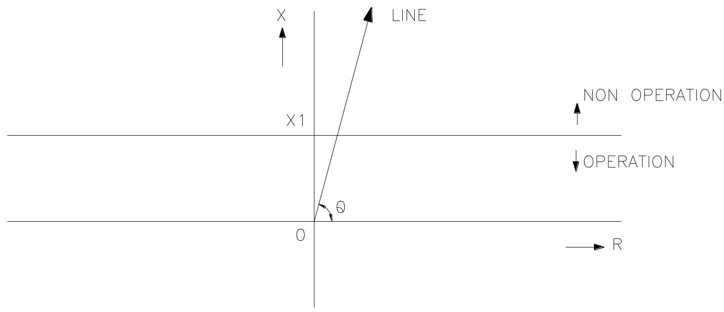


DIRECTIONAL IMPEDANCE RELAY

The directional unit of the relay causes separation of the regions of the relay characteristic shown in the figure by a line drawn perpendicular to the line impedance locus. The net result is that tripping will occur only for points that are both within the circles and above the directional unit characteristic.

The Reactance-type Distance Relay:

Reactance relay measures V/I Sin0 (i.e. Z sin 0 - ⬢). Whenever the reactance measured by the relay is less than the set value, the relay operates. The operating characteristic on R-X diagram is shown in fig

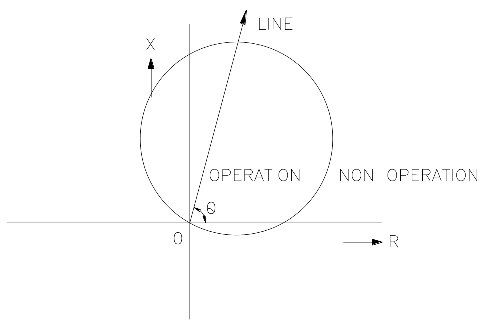


REACTANCE RELAY

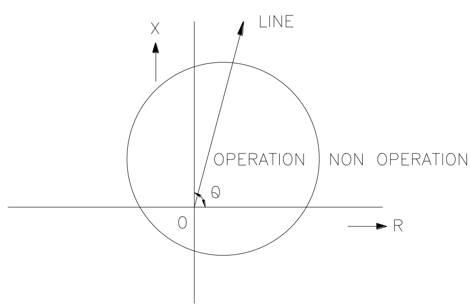
The resistance component of impedance has no effect on the operation of reactance relay, the relay responds solely to reactance component of impedance. This relay is inherently non-directional. The relay is most suitable to detect earth faults where the effect of arc resistance is appreciable.

Mho relay:

This is a directional impedance relay, also known as admittance relay. Its characteristic on R-X diagram is a circle whose circumference passes through the origin as illustrated in figure showing that the relay is inherently directional and it only operates for faults in the forward direction.



MHO RELAY



OFFSET MHO RELAY

Modified impedance relay:

Also known as offset Mho relay whose characteristic encloses the origin on R-X diagram as shown in fig

This offset mho relay has three main applications: -

i) Busbar zone backup

ii) Carrier starting unit in distance/carrier blocking schemes.

iii) Power Swing blocking.

Main Features in Distance Scheme

Distance schemes consist of the following major components:-

i) Starters.
ii) Measuring units.
iii) Timers
iv) Auxiliary relays

i) Starters: -

The starting relay (or starter) initiates the distance scheme in the event of a fault within the required reach (more than zone-3).

Other functions of the starter are: -

a) Starting of timer relays for second and third zones.
b) Starting of measuring elements.

The starters are generally of Mho or impedance type.

With Mho type starters: -

Measuring units for phase and earth faults can be either directional or non-directional as Mho starter is inherently directional.

With impedance type starters: -

Measuring units have to be directional as impedance starters are non – directional.

The under impedance relay can be used in conjunction with the directional relay as starter which will then function similar to the Mho starter.

ii) Measuring units: -

They are generally of a mho or reactance or a combination of mho, reactance and resistance types.

Phase Fault Units:-

These measuring units are fed with line to line voltages (such as Vab, Vbc) and difference between line currents (Ia-Ib). They measure the positive sequence impedance from the relay location to the fault point.

Three such relays respond correctly to all possible single line to ground faults line to line faults, double line to ground faults and 3-phase faults. They however do not respond correctly to earth faults.

Earth Fault Units: -
These measuring units utilize line to neutral voltage (Van, Vbn Vcn) and phase currents (Ia, Ib, Ic). In order to make these units measure the positive sequence impedance correctly, a zero sequence current compensation is to be provided which is obtained by:

KN = (Z0-Z1)/ 3*Z1 (where Z1 = positive sequence impedance of line.
Z0 = Zero sequence impedance of line)

In the current circuit (1+KN) Ia will be fed for the above measurement.

iii) Timers: -
Timer relays when initiated by starters provide the time lag required for zones. They also will be used for zone extension purpose whenever required.

iv) Auxiliary relays: -
Distance scheme comprises of several auxiliary relays, which perform functions such as flag indications, trippings, signaling, alarm etc.

Additional Features in distance schemes: -

i) Power Swing blocking relay
ii) VT fuse failure relay.
iii) Switch onto fault relay
iv) Fault locator
v) Auto-reclosing scheme.
vi) Carrier communication scheme.

i) Power Swing blocking: -
Distance relay which respond to balanced 3-phase changes in the impedance will be affected by power swings. These swings or oscillations occur following a system disturbance such as major load change or a dip in voltage due to delayed fault clearance.

In case of fault, the transition from period of impedance locations (25 to 33% of starter impedance) to fault impedance (starter impedance) is sudden whereas during power swings. The PSB relays use this difference to block the tripping during swings.

ii) **VT fuse failure relay: -**

The distance relays being voltage restraint O/C relays, loss of voltage due to main PT fuse failure or inadvertent removal of fuse in one or more phases will cause the relay operation. The fuse failure relay will sense such condition by the presence of residual voltage without residual current and blocks the relay.

iii) **Switch onto fault: -**

When the line is switched on to a close by fault (say after line clear with earth switch closed), the voltage at the relaying point will be zero. Faults of this type will normally be cleared by backup zones.

The voltage applied to the relay is low and this condition occurring simultaneously with the operation of starter will cause instantaneous trip by SOTF relay. This SOTF feature will be effective only for about 1-2 seconds after the line is charged. Faults occurring after this time will be measured in the normal way.

iv) **Fault locator: -**

It measures the distance between the relay location and fault location in terms of Z in Ohms, or length in KM or percentage of line length.

This relay gets same inputs as the distance relay (connected in series with one of the main relays). The measurement is initiated by trip signal from distance relays.

The fault locator gives the exact location of the fault, thereby reducing the time of restoration.

Factors affecting distance relay operation:-

i) Fault resistance.
ii) Infeed effect.
iii) Branching-off effect.
iv) Load encroachment.

i) Fault resistance:-

Fault resistance has two components:-
a) Arc resistance.
b) Ground resistance.

In a fault between phases, only arc resistance is involved.

For a fault at F, the actual line impedance
= R + JX = ZL

Due to the presence of fault resistance, the impedance measured by the relay
= R + JX + RF = ZR (where ZR > ZL)

Fault arc resistance is given by Warrington's formula:

$$R_{arc} = 8750\ xl\ /\ I^{1.4}$$

where l = length of arc in ft
I = fault current in Amps

The arc resistance has little effect on accuracy of zone-1 unit as it operates instanteously before the arc can stretch appreciably except in case of short lines. Reactance relays are therefore used for short lines where the fault resistance may be comparable with that of the protected lines and also for ground faults where the ground resistance is high.

The arc resistance will have greater impact on accuracy of backup zones (time delayed) as the arc stretches appreciably.

ii) <u>Infeed effect:-</u>

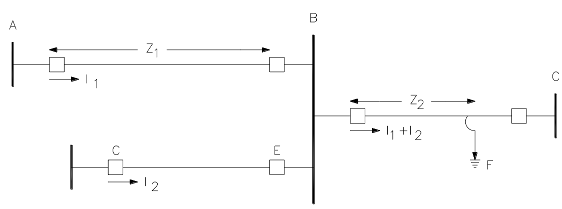
The effect of intermediate current source between relay location and fault point is termed as infeed effect. Consider the sketch indicated in fig ---

A fault at F on the line BC is at a distance of Z1+Z2 for the relay at station A. But when current I2 flows from bus D, the impedance to the fault as seen by the relay at A is
Z1 + Z2 + Z2 x (I2/I1).

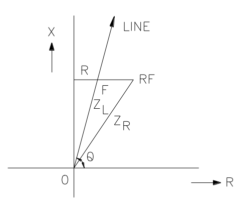
Thus the fault is seen by the relay as farther than what it really is, i.e. <u>distance relay under reaches due to the infeed effect.</u>

The effect of infeed becomes more pronounced with more interconnections at station B.

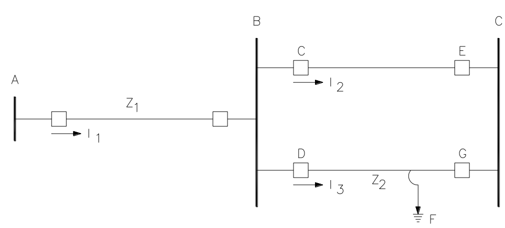
iii) <u>Branching-off effect: -</u>
Consider the sketch indicated in fig ---



INFEED EFFECT



EFFECT OF FAULT RESISTANCE



BRANCHING OFF EFFECT

A fault at F is at the distance of Z1+Z2 for the relay at station A. But when current I1 gets distributed as I2 & I3 at station B, the impedance to fault seen by the relay at station A will be (Z1 + I3/I1 * Z2) which is less than (Z1+Z2).

Then the fault is seen by the relay as nearer than what it really is i.e. distance relay overreaches due to branching-off effect. This overreaching tendency will cause the relay to loose its selectivity.

iv) Load encroachment: -

While protecting long lines the necessary reach may be so large that the minimum service impedance (or load impedance) falls within the region of the starter. This would result in tripping without there being any fault. The two conditions i.e. operation at heavy load and short circuit differ by virtue of phase angle between voltage and current. For the load impedance, the phase angle will be within +30 to -30 Deg. While during short circuits, the fault impedance has a phase angle of 60 to 80 deg. (i.e. line angle).

Load encroachment problem is more pronounced in case of under impedance starters and gets lessened in case of mho, elliptical, lens etc, type of starters. Relays with suitable characteristic on R-X diagram have to be carefully chosen to protect long and heavily loaded lines, and this becomes easily possible with microprocessor based numerical relays.

Non-switched scheme vs switched scheme: -

In an ideal Non-switched scheme, there will be 6 starters, 3 for phase faults and 3 for ground faults. There will be independent measuring units for both phase faults and earth fault for each phase, for all three zones, totaling to 18 units. This scheme is faster and more accurate but is costly.

In the switched scheme, only one measuring unit will be used for all types of faults. This single measuring unit is switched to the correct fault loop impedance by switching-in the respective voltages and currents by the starter.

The reach of the measuring element gets extended to zone-2 and zone-3 after the elapse of corresponding timings through zone extension process. Switched scheme is relatively slow in operation and has the risk of total scheme failure in the event of failure of the only one measuring unit available.

Zone extension schemes: -

As a via media between non-switched and switched schemes, there are schemes with zone extension facility (such as EE make MM3V & MR3V relays). These schemes consists of 3 measuring units for phase faults and 3 measuring units for earth faults (apart from 3 starters).

The reach of the measuring unit gets extended to zone-2 and zone-3 after elapse of corresponding timings through a zone extension process.

Other Operating Characteristics:

Earlier when electromagnetic relays were in use, the characteristics involving straight lines and /or circles on R-X diagram were only possible. With the advent of static relays, microprocessor based relays and presently of numerical relays, any desired/required-operating characteristic is possible giving wider choice for selection of relays. Infact there are relays, which can be programmed remotely.

Application of distance relays:

Since the distance relays are fed from the secondaries of line CTs and bus PTs/line CVTs, the line parameters are to be converted into secondary values to set the relay as per requirements.

$Z_{secy} = Z_{pri}$/Impedance ratio

(where Impedance ratio = P.T.Ratio/C.T.Ratio)

Hence any changes in C.T .ratio has to be effected along with revision of relay settings only.

For the lines, the impedance in Ohms per KM is approximately as under:

KV	Z1 (= Z2)	Line Angle
132 KV	0.4	60 to 70 Deg.
220 KV	0.4	70 to 80 Deg.
400 KV	0.3	80 to 85 Deg.

The line impedance is to be computed depending on line configuration conductor size and clearness. The values in the table are only representative.

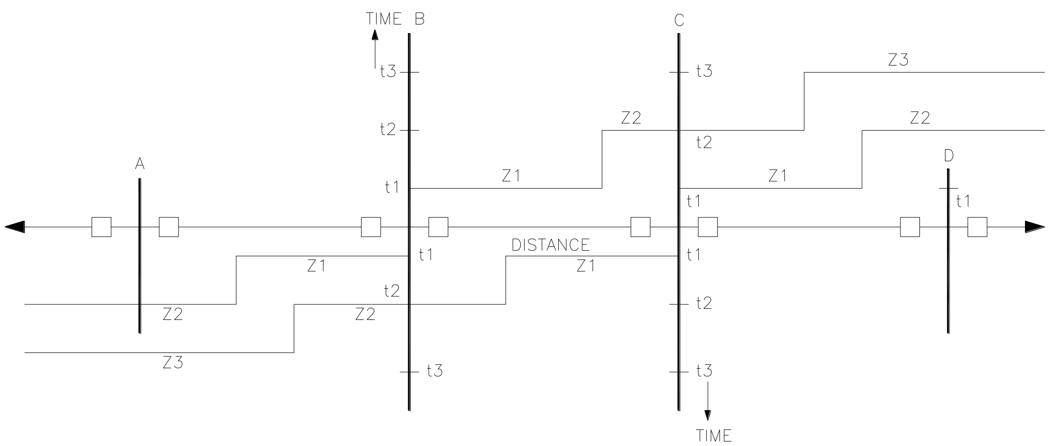
A distance relay is stepped for either 3 zones or 4 zones to provide protection.

To ensure proper coordination between distance relays in power system, it is customary to choose relay ohmic setting as follows: -

S.No.	Zones	Reactance	Time
1.	Zone-1	80% of ZL	Instantaneous (no intentional time delay).
2.	Zone-2	100% of ZL + 40-50% of ZSL	0.3 to 0.4 seconds
3.	Zone-3	100% of ZL + 120% of ZSL	0.6 to 0.8 seconds
4.	Zone-4	100% of ZL + 120% of ZLL	0.9 to 1.5 seconds.

where ZL = Positive sequence impedance of line to be protected.
ZSL = Positive sequence impedance of adjacent shortest line.
ZLL = Positive sequence impedance of adjacent longest line.

Note:
i) Where a three zone relay only is available, the zone 3 will be set to cover the adjacent longest line.
ii) The zonal timings will be carefully selected to properly grade with the relays on all the feeders emanating from the adjacent bus.



THREE ZONE TIME–DISTANCE CHARACTERISTICS

Norms of protection adopted for transmission lines in A.P.System:-

i) 132 KV Lines: -

A switched type distance scheme supplemented by three numbers directional O/L relays and 1 No. directional E/L relay.

ii) 220 KV Lines: -

Two Distance Schemes: -

Main-I: - Non-switched scheme fed from bus PT.

Main-II: - A switched scheme fed from line CVT.

A provision is generally made for the changeover of voltage supply for the distance schemes from the bus PT to line CVT and vice-versa.

Each distance scheme is fed from independent CT secondary cores.

iii) 400 KV Lines:-

Two Distance Schemes:-

Main-I:- Non-switched or Numerical distance schemes

Main-II:- Non-switched or Numerical distance schemes

Details of distance relays:-

1) Make: - GEC Alstom Ltd.

i) MM3V: - It is an electromagnetic type distance relay with:

3-mho measuring units for phase to phase faults.

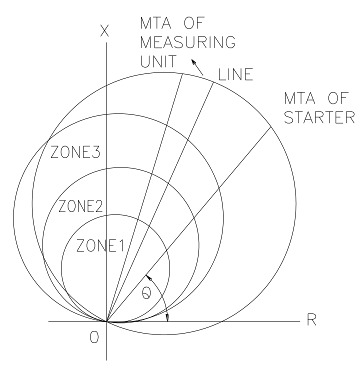
3-mho measuring units for phase to earth faults.

3-mho starting units, each starter being associated with one phase and operating for all faults associated with that phase and one offset mho unit for power swing blocking.

R-X diagram is indicated below
Setting range in ohms for Zone-1

0.834 to 30
1.335 to 48
1.668 to 60
Z2 = 1 to 3.5 times Z1
Z3 = 1 to 5 times Z1

Some of the schemes are provided with a Zone-4 timer to make the scheme works as a 4 zone relay, the starter itself being the 4th zone.



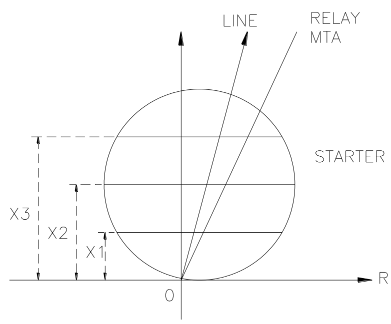
MM3V

ii) <u>MR3V: -</u>

It is an electromagnetic relays with 3 mho units for phase faults, 3 reactance units for earth faults. 3 mho starters, each being associated with one phase for all types of faults and one offset mho unit for power swing blocking.

Setting ranges same as in MM3V.

R-X diagram for phase faults is same as that for MM3V relay and for earth faults it is indicated in figure



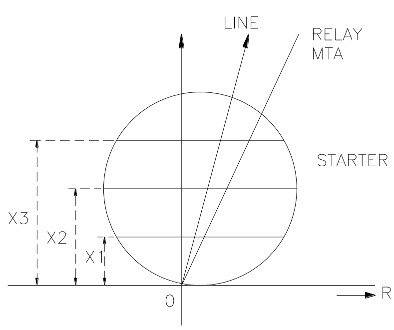
MR3V

iii) <u>RR3V: -</u>

It is an electromagnetic relay with 3 Nos. reactance units for phase faults, 3 reactance units for earth faults, and 3 mho starters per phase for all types of faults and one offset mho unit for PSB. R-X diagram is indicated in figure

iv) <u>SSRR3V: -</u>

It is an electromagnetic switched scheme with two version i.e. with mho or under impedance starter and available in low and high range.



RR3V & SSRR3V

3 under impedance starters directionalised by mho element or 3 mho element starters and for all types of fault, one reactance-measuring unit for phase and earth faults.

Low range relay: Z1 = 0.5 to 7.7. Ohms
(k1 of zone1: 7.7, 3.0, 1.22)

High range relay: Z1 = 1.3 to 20 Ohms
(k1 of zone-1: 20, 7.8, 3.16)
Z2 = (1 to 3.5) times Z1
Z3 = (1 to 5) times Z1

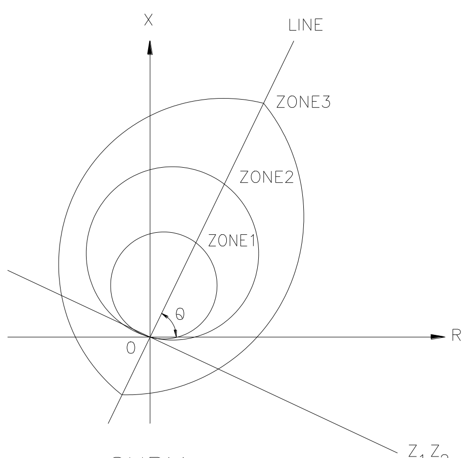
R-X diagram is same as that for RR3V relay.

Few versions do not have separate zone-4 timer. In such relays, zone-4 time = zone-3 time + 150 msec (fixed built-in delay).

v) SHPM (Quadra mho): -
It is a non-switched static scheme with 18 measuring mho units. The zone-3 measuring elements will act as starters, which have either mho or a lenticular characteristic. The operating characteristic on R-X diagram is indicated in figure

The lenticular characteristics allows healthy overloads and hence prevents tripping on load encroachment.

Setting range: - 0.2 to 240 Ohms.



SHPM

It has built-in feature of continuous self monitoring (on demand and periodic self testing).

All the additional features provided by relay can be enabled or disabled with the help of switches provided for them.

vi) PYTS: -

It is a static switched scheme with modular plug-in construction (with built in test points).

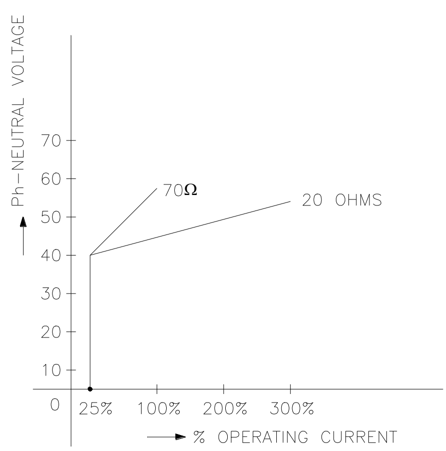
It has 3 under impedance starters and a single mho measuring unit. One U/I unit for power swing blocking. R-X diagram is indicated in figure

Setting range: 0.05 to 40 Ohms, with starter having range of 20 to 70 Ohms.

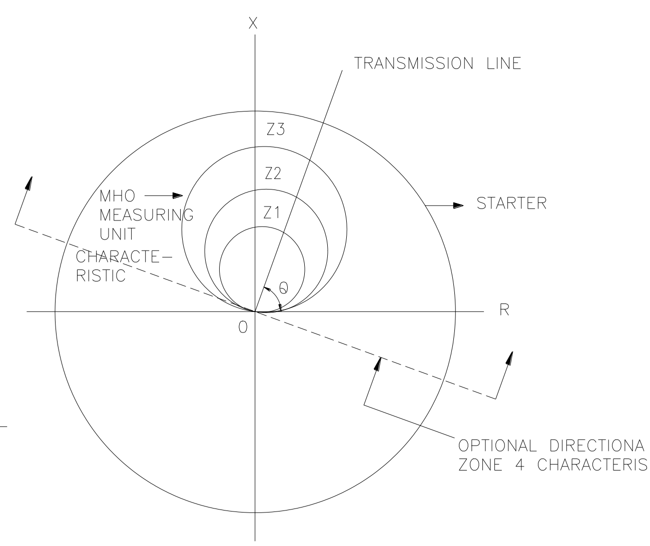
It has an uncompensated U/I starter, which has become a problem due to load encroachment for long lines.

The V-I characteristic of the starter is indicated in above figure.

When the voltage is less than 65% rated, the starter operates at a current greater than 0.25 In. With low voltages at some of the stations, this feature has caused relay to operate unnecessarily.



V-I CHR. OF PYTS



PYTS

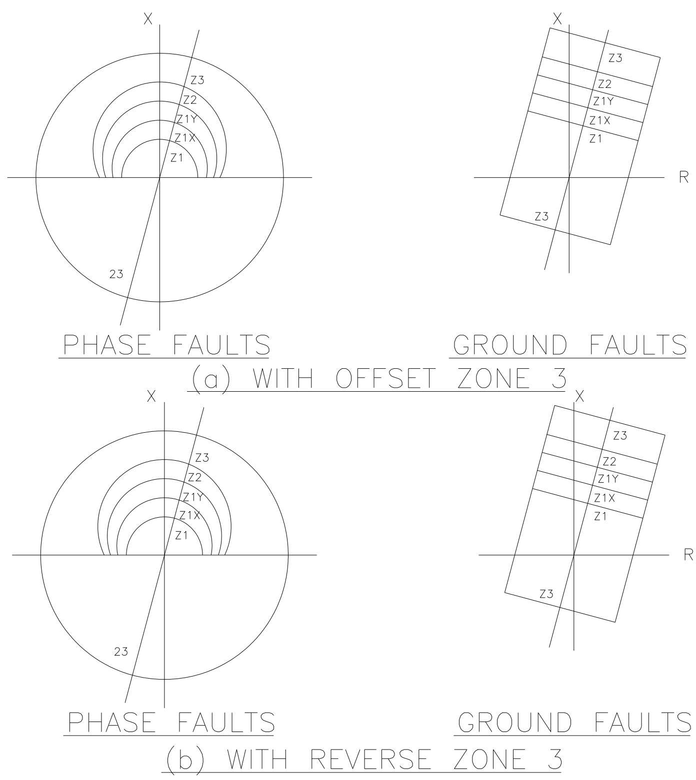
vii) <u>OPTIMHO</u>

Optimho distance relay is a non-switched protection scheme having 18 comparators and upto five zones of protection (three basic zones of measurement and two for zone extension schemes)

The relay has partially cross polarised shaped mho characteristics for zone-1 and zone-2 phase units. The zone-3 for phase faults have offset lenticular characteristics which permit the relay to be applied to long heavily loaded transmission lines without encroachment into the load impedance.

For earth faults, zone-1 and zone-2 units have quadrilateral characteristics with independent reaches in resistive and reactive axes. The zone-3 units are offset quadrilateral.

The zone-3 units for phase and earth faults can be chosen for offset or to see in reverse direction. The relay characteristic is indicated in Fig.



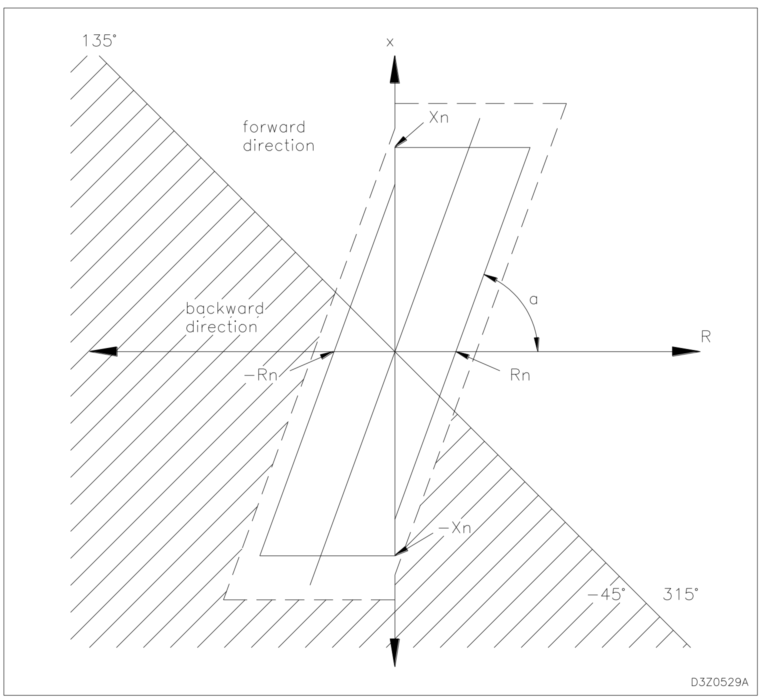
OPTIMHO

On event of failure of quadrilateral comparators, mho/lenticular comparators are automatically enabled but vice versa is not possible. The relay has self testing facility. It has 8 groups of settings and any one group can be set active.

PD – 521: -

a) It is a numerical protection relay with polygon characteristics.
b) It consists of four impedance zones with independent R and X values for each zone
c) Zone – 4 can be utilized as a special zone for cabie protection.
d) R – X diagram as indicated in figure.
e) Through MMI, one can enter and edit the settings (The settings are password protected)

Setting Range	:	0.1 to 2000 Ohms.
Timers	:	0 to 10 Secs.



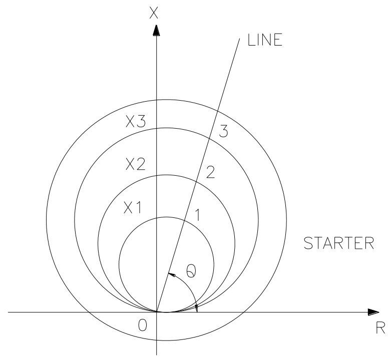
PD. 521

2) Make: - BBC/HBB

i) LZ96:

It is a non-switched scheme with 3 underimpedance measuring units common for ground and 3-phase faults.

3 Nos. under impedance (offset mho) starters, one under-impedance unit for all possible phase to phase faults. R-X diagram is indicated in figure

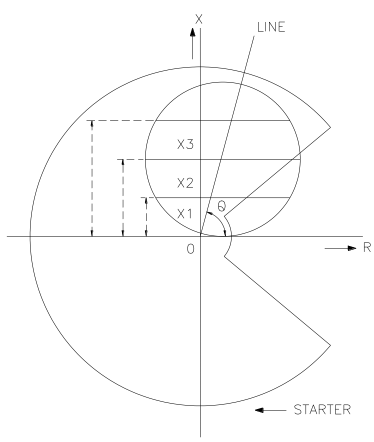


LZ96

Forward and reverse reach can be selected independently in starters (with zone-4 time setting).
Setting range: 0.1 to 100 Ohms.

ii) LIZ6: -

It is a switched scheme with 3 under-impedance starters, 3 overcurrent starters and one neutral current starter. It has one reactance measuring unit for all faults. With the provision of angle replica unit the relay has special operating characteristic on R-X diagram indicated in figure, which permits high loading on long lines. This being the initial versions of static relays there have been number of component failure and are being phased out.



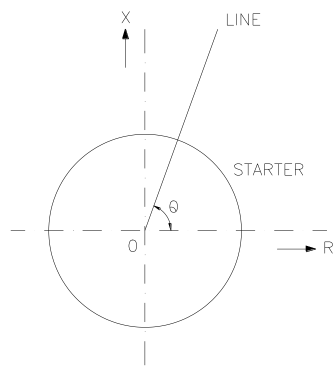
LIZ-6

iii) <u>L3 relays: -</u>

a) <u>L3WYS:</u>

This relay consists of 3 under impedance starters and a single directional reactance measuring unit (CM relay).

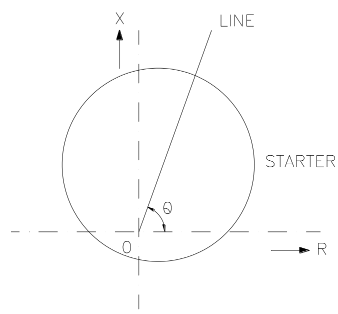
It is four zone relay, the zone-4, starter step being non-directional. Time settings for all the four zones (including Zone-1) can be varied from 0.1 to 5 seconds. R-X diagram is indicated in figure.



L3WYS

b) <u>L3wyas: -</u>

This is similar to L3WYS relay except that the U/I starters are provided with compounding chokes thereby shifting the circle, making it an offset mho as indicated in figures.



L3WYAS

It is also supplemented by Yi/L - power swing blocking unit.

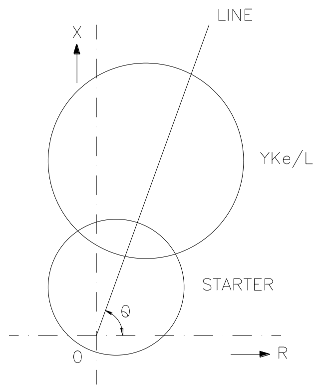
iv) <u>L6ft: -</u>

It is high speed, single step distance relay usually supplemented to L3wyas or L3wys. It is set to protect 80% of line and without any time delay.

v) <u>Yke/l relay: -</u>

This consists of three under impedance starters, used in conjunction with L3wyas relays. By provision of compounding chokes, the operating region of the Yke/l relay is shifted much above the origin of the R-X diagram. The operating characteristic of the combination of L3wyas and Yke/l relay is indicated in figure.

It may be seen from the diagram that this combination permits much higher loading and protects longer lines, without any problem of load encroachment.



L3WYAS + YKe/L

3) <u>Make: ABB: -</u>

i) <u>RYZFC: -</u>

It has come into service in the initial stage of the advent of static relays, has 3 mho measuring units for earth faults, one mho unit for phase faults and 3 under impedance starters.

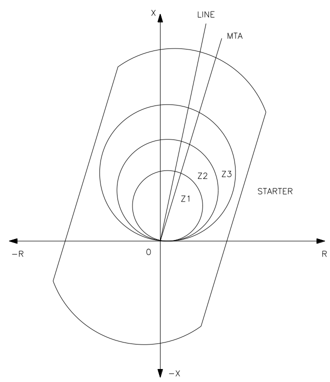
In addition, this relay has negative sequence current starter with a fixed setting of 20% of In, which causes the relay to trip in Zone-4. The starter can be made to operate either as a circle or as oval.

R-X diagram is indicated in figure.

Setting range: - 1.8 to 200 Ohms.

a) This relay is found to lose its directional sensitivity for closeby reverse faults and hence not recommended for use on feeders emanating from generating stations.

b) Also the negative phase sequence starter is found to respond to very far end faults.



RYZFC

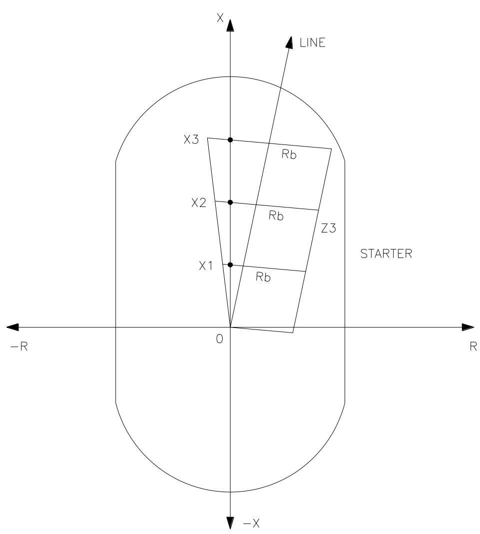
ii) RAZOG: -

It is a switched scheme with 3 under impedance starters and one reactance measuring unit. It has quadrilateral characteristic.

R-X diagram is indicated below.

Setting range: 0.25 to 64 Ohms.

The starter can be made to operate either as a circle or oval.



RAZOG

iii) <u>RAZFE:</u>

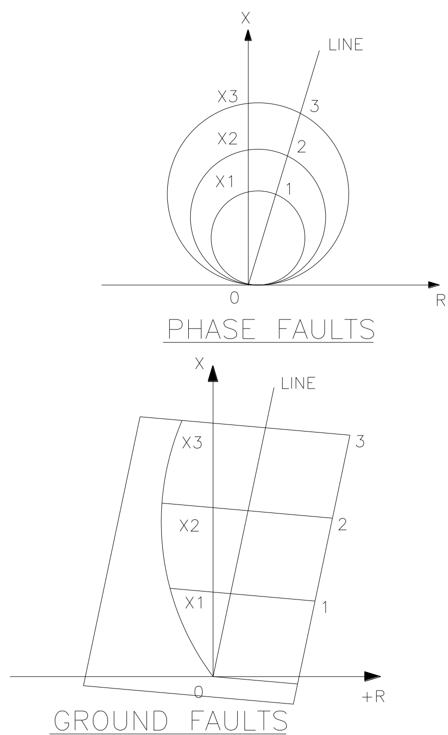
It is static three zone non-switched scheme.

For ground and 3-phase faults, the distance relay has a reactance like operating characteristic, the reactance line being inclined by a few degrees towards resistance axis on R-X diagram, which provides excellent margin for high resistance faults and minimises effects of load current and remote ends infeed on distance measurement R-X diagram is indicated below.

To avoid load encroachment problem, the relay is provided with blinder, which has independent settings in resistive and reactive directions.

For phase to phase faults, mho units are used.

Setting rage: 0.25 to 64 Ohms.

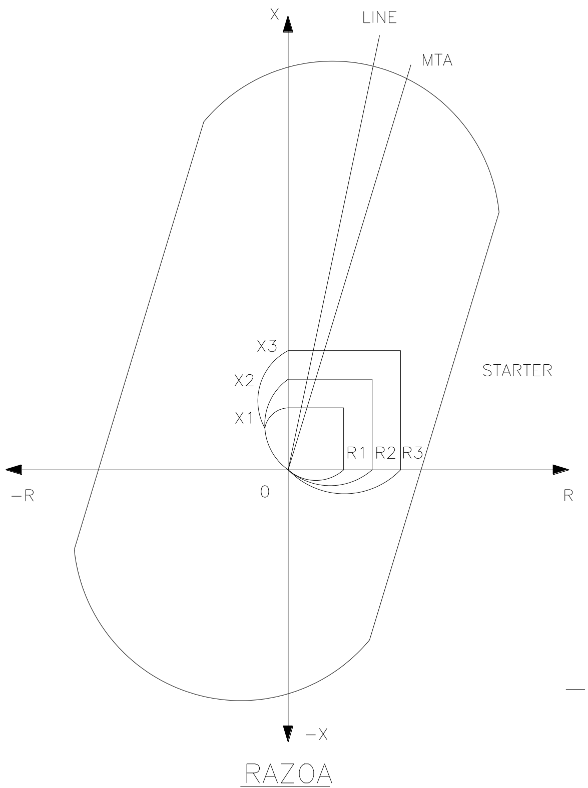


RAZFE

iv) <u>RAZOA: -</u>

It is a static scheme having 3 under -impedance starters and one measuring unit. The directional measuring unit has got quadrilateral characteristic with independent settings in resistive and reactive directions. R-X diagram is as indicated.

The U/I starter can be made to operate with a circle or oval characteristic with a selectable switch (S3: 1 ON for circle OFF for oval in RGZB module).



RGSB Module:

Directional	: S1: 1 - OFF
Non-directional	: S1: 1 - ON
Setting range	: 0.16 to 64 Ohms.

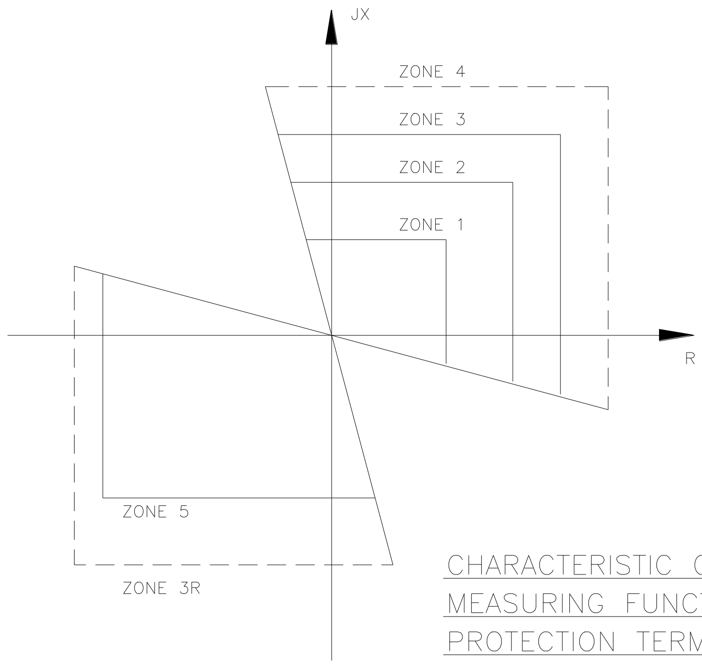
(v) RELZ-100:

It is a numerical relay with quadrilateral impedance units for phase and earth faults. Each measuring unit has individual and independent setting of the reach in resistive and reactive directions, as well as for the zero sequence compensation factor, KN. Entire Zone-3 reach (in forward direction) is available in reverse direction with a separate timer T3R. R-X diagram is as indicated

Four groups of setting parameters are possible to suit different system conditions. Only one of the groups will be in service by choice. It has continuous self monitoring and self testing feature and indicate the same by extinguishing "Relay Available" LED on the relay. Through MMI, one can enter; edit the settings, read the mean service values of line voltage, current, real, reactive power and frequency. It stores data of latest 3 disturbances occurred. (The settings are not password protected).

Setting rage: 0.1 to 150 Ohms.
Timers: 0 to 10 Secs.

It has a feature which does overload supervision and unsymmetrical load condition, which can be used for alarm or trip.



CHARACTERISTIC OF THE IMPEDANCE MEASURING FUNCTION IN THE LINE PROTECTION TERMINAL REL 100

vi) RADSL: -

This pilot wire protection scheme used for protection of short lines. It is very fast operating relay, clearing the faults in 100% of line without any time delay. This is commissioned on 220 KV KTS 'C' Station - KTS V Stage tie lines 1 & 2 at both ends as Main-1 protection scheme (Main-II being RELZ-100 relay).

Likewise GEC make FAC34 pilot wire differential relays are provided on 220 KV NTPC - RAMAGUNDAM tie lines 1 & 2 with backup O/L, E/L relays.

4) Make: - Universal Electric

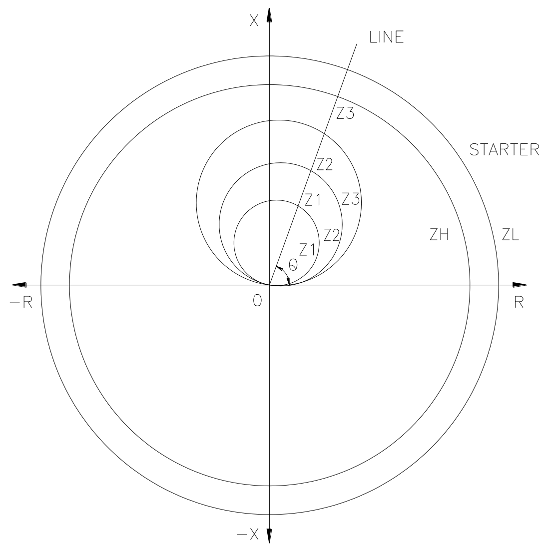
i) MDT45B:

It is a non-switched 3-zone distance scheme with 18 measuring units, 3 Nos. low set starters ZL and 3 Nos. high set starters ZH. It is available in two ranges low and high.

R-X diagram is indicated in figure.

a) For Low range:
Reactance Measuring units for Zone-1 & Zone-2.

b) For High range:
Mho measuring units for Zone-1 & Zone-2.



MDT 45B

ii) <u>MDTB101:</u>

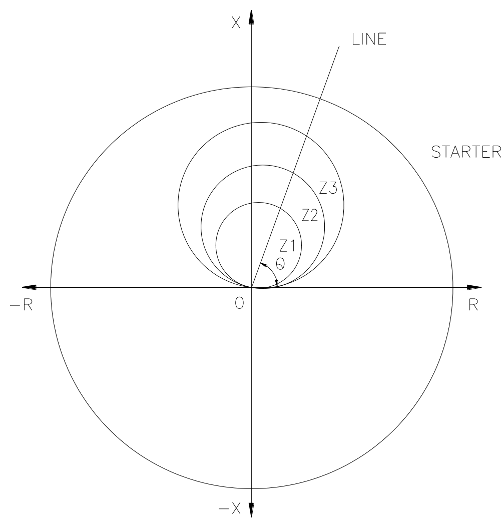
It is switched scheme, with 3 impedance starters, one neutral overcurrent starter and one mho measuring unit.

R-X diagram is indicated in figure.

This relay has a V-I characteristic similar to that of PYTS relay. When the voltage is less than 65% rated, the starter operates at a current greater than 0.25 In.

For 220 KV lines, the settings on Main-I distance relay must be on par with that of Main-II relay and vice-versa.

For 132 KV lines, distance relay along with directional O/L, E/L relays are used. The operating time of O/L, E/L relays for adjacent bus faults are set equal to or more than zone-2 time of distance relay.



MDTB 101

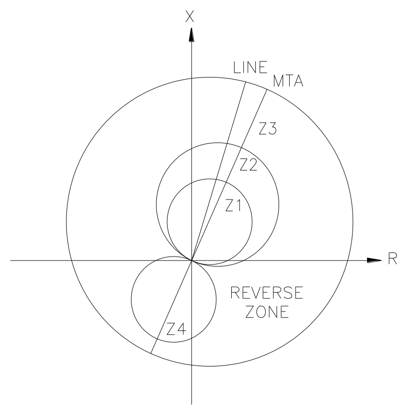
5) <u>Make: - Easun Reyrolle: -</u>

i) <u>THR4PE24: -</u>

It is static non-switched scheme with 3 forward zones and 1 reverse zone consists of a total of 24 measuring units. 12 Nos. mho units for zone-1 & zone-2 for phase and earth faults. 6 Nos. offset mho units for zone-3, 6 Nos. Mho units for reverse reach.

R-X diagram is indicated in figure.

It has reverse reach set to (c x zone-1) for phase faults and (c x zone-1) (1+KN) for earth faults, KN being compensation factor. Generally c is set equal to '1'.



THR4PE24

ii) <u>THR4PE1: -</u>

It is static switched scheme with 3 offset mho starters and one mho measuring unit.

R-X diagram is indicated in the figure.

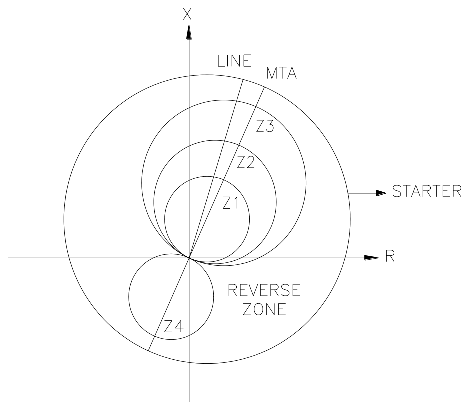
It is available in low and high ranges: -

<u>Setting range: -</u>

Low range: - 0.08 to 9.5 Ohms (with A:0.8 to 9.6)

High range: - 0.4 to 47.5 Ohms (with A: 4 to 48)

The starter has a built in reverse reach, equal to 50% of forward reach for phase faults and 50% of forward reach (1+KN) for earth faults, KN being compensation factor.



THR4PE1

Make: - Seimens Ltd.

7SA511 relay:

It is a numerical protection scheme with 16 bit microprocessor. With three version of detectors.

i) Phase selective overcurrent fault detector.

ii) Voltage controlled (under-impedance) fault detector (with independent R & X reaches) and

iii) Polygonally shaped angle-dependent impedance fault detector.

It has five zones (two of which can be used for communication schemes).

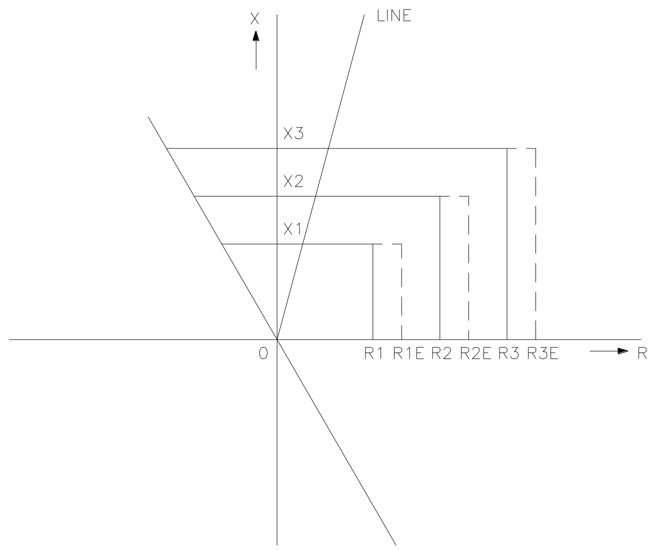
R-X diagram is indicated below.

Apart from common features, it provides Emergency overcurrent function, which comes into picture when main distance scheme is blocked due to VT fuse failure conditions.

It provides two user defined logic functions. It has continuous self monitoring and self testing feature. It stores data of latest three faults and measures values of load current, operating voltage, power and frequency continuously.

Setting range: 0.1 to 200 Ohms with 0.0 to 32 sec (in step of 0.01 sec) timers.

Four groups of settings are possible to suit different system conditions. Only one of the groups will be in service by choice.



7SA511

SEL – 321: - It is numerical relay with

a) Four Mho zones for phase faults with independent phase to phase overcurrent supervision.

b) Four ground faults for Mho and Quadrilateral zones with independent phase and residual overcurrent supervision and zero sequence compensation.

c) Two Quadrilateral zones for power swing blocking.

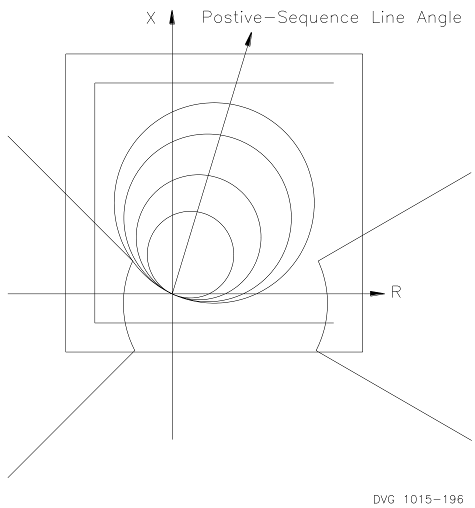
d) Load-encroachment characteristics.

e) Instantaneous, Definite time and IDMT overcurrent characteristics.

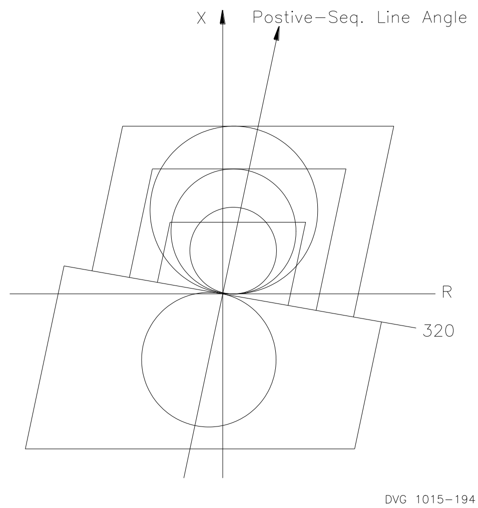
f) Six (6) setting groups are available in the scheme.

Setting ranges:-

For Mho zones	:	0.25 to 320 Ohms (Secondary)
For Quadrilateral Zones	:	
Reactance	:	0.25 to 320 Ohms (Secondary)
Resistance	:	0.25 to 250 Ohms (Secondary)
Timers	:	0-2000 Cycles



Three−Phase and Phase−Phase Distance Characteristics



Ground Distance Characteristics

SEL321

Relay indications: purpose and meaning: -

The relay indications are a guide to identify the type and broad location of fault. They are the means to assess the relay performance by tallying with the actual faults occurred. They help in review and analysis of the trippings occurred. Different manufacturers used different symbols/flags of signaling different types of faults.

Whenever the relays operate, their indications should be noted before they are reset

Relay indications with their meanings on various types and makes of relays are indicated in the following table.

CHART SHOWING RELAY INDICATIONS FOR VARIOUS RELAYS

S.No	Make & Type of Relay	Distance protection operated Trip.	Type of Fault with Indications				Zone Indication				Switch On-to Fault Trip	Power Swing Blocking	Carrier Relay Operated	V.T Fuse Failure
			Type Phase to phase	Indica-tions	Type Phase to Earth	Indica -tions	Z1	Z2	Z3	Z4				
1.	EE/GEC MM3V		R-Y	30(A-B)	R-E	30A		30G	30G	2/21			85X	Tripping Blocked
			Y-B	30(B-C)	Y-E	30B	30G	30H	30H					
			B-R	30(C-A)	B-E	30C			30J					
2.	MM3T		R-Y	AB	R-E	AN	Z1	Z2	Z3					Tripping Blocked
			Y-B	BC	Y-E	BN								
			B-R	CA	B-E	CN								
			R-Y-B	AB,BC,CA										
3.	RR3V		R-Y	30(A-B)	R-E	30A	30G	30G	30G					Tripping Blocked
			Y-B	30(B-C)	Y-E	30B		30H	30H	2/21				
			B-R	30(C-A)	B-E	30C			30J					
4.	MR3V		R-Y	30(A-B)	R-E	30A	30G	30G	30G					
			Y-B	30(B-C)	Y-E	30B		30H	30H	2/21				
			B-R	30(C-A)	B-E	30C			30J					
5.	MR3V		R-Y	30A	R-E	30D	30G	30G	30G					Tripping Blocked
			Y-B	30B	Y-E	30E		30H	30H					
			B-R	30C	B-E	30F			30J					
6.	SSRR3V		R-Y	A,B	R-E	A	Z1	Z1,Z2	Z1,Z3					
			Y-B	B,C	Y-E	B				2/21				
			B-R	C,A	B-E	C								
			R-Y-B	A,B,C										

CHART SHOWING RELAY INDICATIONS FOR VARIOUS RELAYS

S.No	Make & Type of Relay	Distance protection operated Trip.	Type of Fault with Indications				Zone Indication				Switch On-to Fault Trip	Power Swing Blocking	Carrier Relay Operated	V.T Fuse Failure
			Type Phase to phase	Indica-tions	Type Phase to Earth	Indica-tions	Z1	Z2	Z3	Z4				
7.	EE/GEC PYTS		R-Y	A,B	R-E	A		**Z2**	**Z3**	**Z4**	SOTF	PSB		
			Y-B	B,C	Y-E	B								
			B-R	C,A	B-E	C								
			R-Y-B	A,B,C										
8.	SHPM "QUADR OMHO"		R-Y	A,B	R-E	A		**Z2**	**Z3**		SOTF		AIDED TRIP	V-FAIL
			Y-B	B,C	Y-E	B								
			B-R	C,A	B-E	C								
			R-Y-B	A,B,C										
9.	LZ-96	D	R-Y	R,S	R-E	R								
			Y-B	S,T	Y-E	S								
			B-R	T,R	B-E	T		2	3	4			HF (Yellow)	
			R-Y-B	R,S,T										
10.	LIZ-6		R-Y	R,S	R-E	R,E		T2	T2, T3	T2,T 3T4				
			Y-B	S,T	Y-E	S,E								
			B-R	T,R	B-E	T,E								
			R-Y-B	R,S,T										

CHART SHOWING RELAY INDICATIONS FOR VARIOUS RELAYS

S.No	Make & Type of Relay	Distance protection operated Trip.	Type of Fault with Indications				Zone Indication				Switch On-to Fault Trip	Power Swing Blocking	Carrier Relay Operated	V.T Fuse Failure
			Type Phase to phase	Indica-tions	Type Phase to Earth	Indica-tions	Z1	Z2	Z3	Z4				
11.	L3wyas / L3wys/ Lz3s (signal Block)	PD (D)	R-Y	PAR(R), PAS(S)	R-E	PAR(R) PE(E)		PSII (2)	PSII PS-III (2) (3)	PSII PS-III (2) (3)	PTa		PtrH	
			Y-B	PAS(S) PAT(T)	Y-E	PAS(S) PE(E)								
			B-R	PAT(T) PAR(R)	B-E	PAT(T) PE(E)								
12.	L6FT	PD3										PTa5		
13.	ASEA / ABB :-													
	RYZFC	UD	R-Y	R,S	R-E	R		2	2,3	2,3,4		P	CS/CR	
			Y-B	S,T	Y-E	S								
			B-R	T,R	B-E	T								
			R-Y-B	R,S,T										
14.	RAZOG	UD	R-Y	R,S	R-E	R		2	2,3	-		P		
			Y-B	S,T	Y-E	S								
			B-R	T,R	B-E	T								
			R-Y-B	R,S,T										
15.	RAZFE	U	R-Y }	2-phase	R-E	RN	Z1	Z2,	TK2,			P		
			Y-B }		Y-E	SN	Z2	TK 2	TK3					
			B-R }		B-E	TN								
			R-Y-B	3-Phase										

CHART SHOWING RELAY INDICATIONS FOR VARIOUS RELAYS

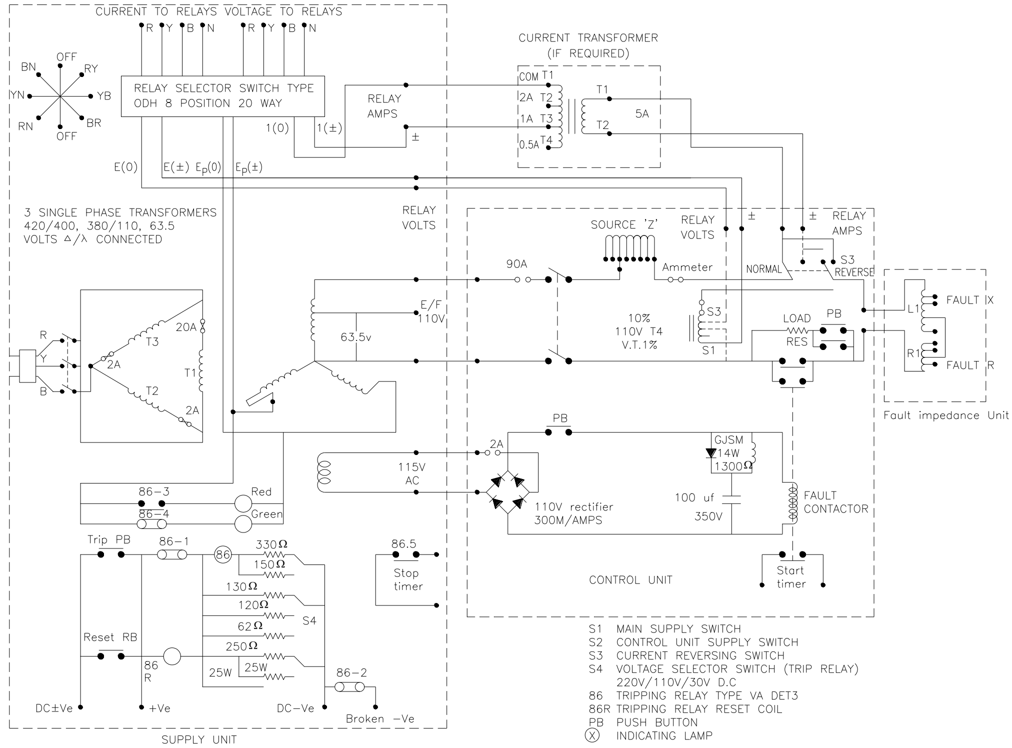
S.No	Make & Type of Relay	Distance protection operated Trip.	Type of Fault with Indications				Zone Indication				Switch On-to Fault Trip	Power Swing Blocking	Carrier Relay Operated	V.T Fuse Failure
			Type Phase to phase	Indica-tions	Type Phase to Earth	Indica-tions	Z1	Z2	Z3	Z4				
16.	ASEA/ ABB													
	RAZOA	Trip	R-Y	R,S	R-E	R,N		2	2,3	2,3,4		P		
			Y-B	S,T	Y-E	S,N								
			B-R	T,R	B-E	T,N								
			R-Y-B	R,S,T										
17.	REL-100	Trip Z	R-Y	PSR,PSS	R-E	PSR,PSN	TRZ1	TRZ2	TRZ3	TRZ3R	TREF	PSB	CRZ/CBZ	VTF /
			Y-B	PSS,PST	Y-E	(Trip-R)	Zm1,	Zm2,	Zm3	Zm3R	SOTF			VTS
			B-R	PST,PSR	B-E	PSS,PSN (Trip-S)	Zm2,	Zm3		(Reverse)				
			R-Y-B	PSR,PSSPST		PST,PSN (Trip-T)	Zm3							
18.	UE MDT-45B		R-Y	AB,ZIS	R-E	A	Z1	Z2	Z3	Z4	SOFT	PSB	RR/CS	SV
			Y-B	BC,ZIS	Y-E	B								
			B-R	CA,ZIS	B-E	C								
			R-Y-B	ABC,ZIS										
19	UE MDTB-101		R-Y	AB	R-E	A		Z2	Z3	Z4	SOFT		CAT	VTF
			Y-B	BC	Y-E	B								
			B-R	CA	B-E	C								
			R-Y-B	ABC										
20.	ER THR4PE24	PO	R-Y	r, y	R-E	r							Pt	
			Y-B	y, b	Y-E	y		1	2	3				
			B-R	b, r	B-E	b								
			R-Y-B	r, y, b										

CHART SHOWING RELAY INDICATIONS FOR VARIOUS RELAYS

S. No	Make & Type of Relay	Distance protection operated Trip.	Type of Fault with Indications				Zone Indication				Switch On-to Fault Trip	Power Swing Blocking	Carrier Relay Operated	V.T Fuse Failure
			Type Phase to phase	Indica-tions	Type Phase to Earth	Indica-tions	Z1	Z2	Z3	Z4				
21.	THR4PE1	PO	R-Y	r, y	R-E	r, Earth		2	3	2&3				
			Y-B	y, b	Y-E	y, Earth								
			B-R	b, r	B-E	b, Earth								
			R-Y-B	r, y, b										
22.	SIEMENS RIZ-24a		R-Y	JR,JS,R,S	R-E	JR,TM, R,M		T2	T3	T4		P		
			Y-B	JS,JT,S,T	Y-E	JS,JM,S,M								
			B-R	JT,JR,T,R	B-E	JT,JM,T,M								
			R-Y-B	JR,JS,JT, R,S,T										
23.	75A511		R-Y	LED 2,3, 12,13	R-E	LED 2,5,12	LED 7	LED 8	LED 9	LED 10			AR	
			Y-B	LED 3,4, 13,14	Y-E	LED 3,5,13								
			B-R	LED 4,2, 14,12	B-E	LED 4,5,14								
			R-Y-B	LED 2,3, 4,12,13,14										
24	IGE:-													
	a) GCY-51A		R-Y	R,Y										
			Y-B	Y,B			I	II	III					
			B-R	B,R										
	b) GCX-51A				R-E	R								
					Y-E	Y								
					B-E	B								

Distance relays in service in A.P.System:

S.No.	Make	Main-I distance relay	Main-II relay
1.	GEC Alstom/ EE	MM3V	MR3V
		-	SSRR3V (MHO/UI starter)
		-	RR3V
		SHPM	PYTS
		OPTIMHO	
2.	ABB/ASEA	RELZ-100 |	RAZOA
		RAZFE |	
		RYZFC	RAZOG
		RADSL	
3.	BBC/HBB	LZ96	LIZ6
		L3wyas+L6ft	
		L3wys+L6ft	
4.	SEIMENS	7SA511	7SA511
		-	RIZ24a
5.	ER	THR4PE24	THR4PE1
6.	UE	MDT45B	MDTB101



SCHEMATIC DIAGRAM 3 PHASE PROTABLE DISTANCE TEST SET MK11 (EE ZFB)

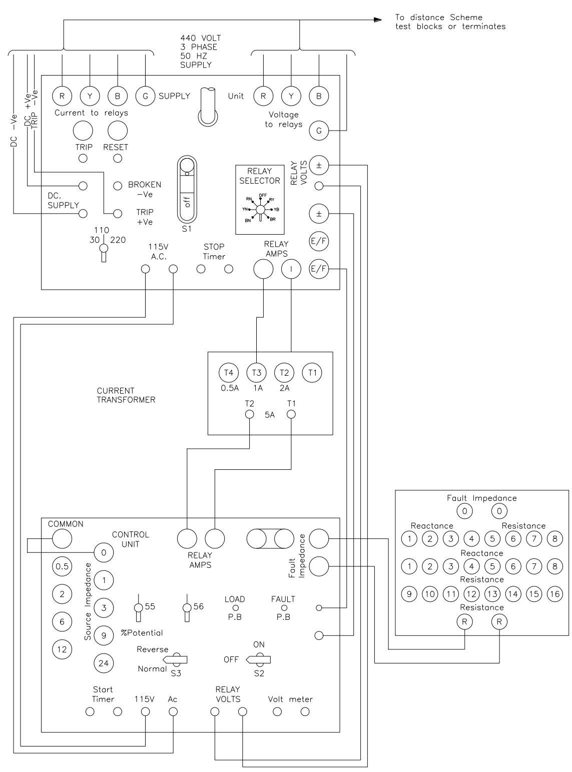


FIGURE 3